ACCOUNTING FOR LONG-LIVED PRODUCTIVE RESOURCES--THE DEVELOPMENT AND EVALUATION OF GENERAL ENERGY SYSTEMS MEASUREMENT PROCEDURES

By

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ACCOUNTING FOR LONG-LIVED PRODUCTIVE RESOURCES--THE DEVELOPMENT AND EVALUATION OF GENERAL ENERGY SYSTEMS MEASUREMENT PROCEDURES

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In a market economy, money functions as the motivator (via the operation of the profit system within the constraints of man's social system) that determines what goods and services will be produced, who will produce them, and how they will be produced. Accounting is the responsible communication subsystem within man's social system which reports the relevant economic information that is being communicated by monetary transactions (i.e. money flows). A necessary step for this communication process is the determination of the appropriate measurement base to be used as the valuation coefficient for long-lived productive resources. This determination requires investigation of two basic questions. First, which measurement base provides the most useful data to decision-makers? Extensive review of previously completed work in this area leads to the conclusion that the answer to this inquiry requires additional

empirical investigation into the behavioral reactions of decision-makers to accounting information.

Secondly, how is the selected measurement base to be calculated? The primary purpose of this study is to develop and evaluate the use of general energy system statistical procedures for calculating a measurement base in terms of current replacement cost.

General Energy Systems Theory

The basic concepts of general energy systems theory may be stated as follows:

1. All economic goods and services are the result of some form of work which generally can be physically measured and stated in terms of energy equivalent measurement units.

2. Money is paid for most goods and services; therefore, it may be concluded that money circulates counter to energy. Accordingly, money serves as a feedback mechanism for communicating to producers the "form" of energy flow desired by consumers.

3. Any economic good or service can be measured in terms of either an "energy equivalent" or a "currency based" common measurement equivalent.

The General Energy Systems Ratio of Exchange Model

The observed relationships between energy and money are utilized to formulate a model to calculate an average price per unit of energy for any specific, or any aggregate grouping of, economic good(s). This energy price may then be used to estimate the ratio of exchange, for the current time period, for any specified economic good(s), including long-lived productive resource(s).

Evaluation of the Model

The general energy systems model is evaluated with reference to the most commonly observed criticisms of earlier research efforts to estimate replacement cost by calculating current ratios of exchange. The conclusions resulting from this evaluation may be summarized as follows:

1. The general energy systems model is internally consistent. Furthermore, its results are logically consistent with those expected utilizing currently accepted economic price theory.

2. The energy systems model enables the investigator to identify that portion of any overall price change for a long-lived resource which is caused either by changes in productive efficiency or by changes in input transformation efficiency.

3. Whether the energy systems approach will provide "objective" estimates of current replacement cost is an empirical question which cannot be resolved at this time due to data limitations.

Chairman

CHAPTER I
INTRODUCTION

In man's diverse, technologically advanced social system money has evolved as the principal measurement unit for expressing exchange relationships between the myriad of heterogeneous goods and services commonly encountered. A price, then, is the ratio of a number of monetary units to a related quantity of some physical good or service. Therefore, the price of a good represents the command which that particular good exerts on money, and indirectly, the command it has on all goods and services by way of their monetary prices. For example, if wheat sells for $4.00 per ton and corn for $3.00 per ton, then ten tons of wheat can be sold for $40, which can be used to buy 13 and 1/3 tons of corn. Thus, in an exchange relationship ten tons of wheat will command 13 and 1/3 tons of corn. Moreover, as supplies of the myriad of goods available in an economy change along with changes in consumer preferences, the exchange ratios (prices) of all goods constantly change.

With reference to accounting purposes, two kinds of prices may be identified. The most obvious may be termed the ratio of exchange and it is the ratio of the amount of money paid in an actual economic transaction to the physical quantity of economic goods received in exchange for the money.[1]* Thus, if ten dollars is paid for two shirts, the ratio of exchange is five dollars per shirt. A second kind of price may be referred to as a valuation coefficient and is generally thought to be less obvious than the first.[2] Valuation is the process whereby the equivalent in some measure of value is calculated for a physical quantity of the objects being valued regardless of whether these objects are going to be exchanged. Thus, the valuation coefficient is the ratio between the units of the measure of value and the quantity, expressed in some physical terms, of the object which is valued.[3] For example, a shirt identical to the ones referred to above, may be valued at five dollars, which is simply a figure expressing the equivalent of the shirt in some measure of value whether it is exchanged or not.

Although exchange ratios typically refer to actual or potential flows of exchange (currency for physical goods or vice versa) and valuation coefficients typically refer to stocks or storages of physical objects, valuation coefficients are generally based in some way or another on exchange ratios, past, present, or future. Thus, a valuation may be made by recording the original exchange ratio when the object last participated in an exchange (when it was purchased) and by making some allowance for depreciation, or appreciation, since that exchange. Or it may be made by observing the actual exchange ratios of similar objects which are being exchanged at the moment. Or it may be made by estimating the ratio at which the object will be exchanged at some future date.

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*References are listed at the end of the chapters.

Energy, Economics, and Accounting

Economics is concerned with investigating the exchange component within man's social system. Therefore, economists are primarily concerned with analyzing and explaining the motivational and behavioral responses of producers and consumers to changing exchange relationships. Moreover, economic studies typically involve analysis of what is referred to in energy systems theory as money feedback loops.[4] All production units and consumer units are interconnected by these feedback loops as, in the absence of such a connecting feedback, a given unit will cease to function as a viable economic entity as soon as its storages of resources are consumed. That is, each production unit is also a consumer unit; likewise, each consumer unit must be a production unit providing either useful services or useful goods to some other unit. Therefore, each unit of society must have an output of something for which money is received, and each unit then spends at least a portion of those receipts purchasing the resource inputs that it needs in order to continue to produce its output. Moreover, economic analysis has shown that any producer unit, over the long run, must receive for its output at least a dollar amount equal to the cost of the resource inputs needed to make that output or it will eventually cease to function as a viable economic entity.

Within this economic system the function of accounting may be stated as to collect, process, and report to outside parties, as well as to management, information concerning the currency flows of specific accounting entities. In other words, the function of the accounting component within man's social system is to provide information to the individuals within the social system who operate the control levers which direct work flows toward useful ends for the whole of society. Moreover, the information provided should enable the users of such information to make better decisions concerning their planning and control functions than if they operated without the information.

Management Evaluation by Outside Parties Using Accounting Data--A Brief Description

When considering any economic venture, decision-makers balance that which is expected to be given against that which is expected to be received and the venture is started only if the latter appears to be in excess of the former. Since the purpose of accounting is to furnish the information necessary to evaluate past managerial judgment (via evaluation of the actual results of current economic activity), it appears that the most relevant and useful evaluation method is the association of accomplishment with effort. However, as there are many heterogeneous input and output goods available, each of which provides varying degrees of satisfaction, or economic utility, to individual entities, some standard measuring unit must be used. Thus, currency has evolved as the common denominator for describing different commodities in terms of a standard measuring unit and the association of giving with receiving in accounting is accomplished by way of currency flows. Inflows of currency in exchange for goods and services are referred to as revenues and are used as a measure of accomplishment; outflows are called expenses (or costs), and are used as a measure of effort. Moreover, an excess of revenue over expenses (which is referred to as income) indicates that the goods and services which management has elected to provide have proved acceptable in the market; an excess of expenses over revenue (a loss) indicates the goods and services provided are not acceptable at an asking price high enough to generate income. Because this basic technique for evaluating the results of economic activity has existed for many years, accountants have developed a very refined set of procedures so as to explicitly attempt to match expenses incurred against revenue earned (this process is generally referred to as accural accounting). Also, a financial statement, the income statement, has been developed to communicate revenue and expense data. However, when a specific entity's management team is evaluated via comparison with other management teams the evaluation procedure generally includes an additional step. That is, evaluation is accomplished by relating the income earned through the efforts of each management team, considering also the capital (i.e. the currency value of all the heterogeneous resources employed) required by each to produce the given income (in other words, by comparing the respective rates of return on investment). Thus, proper economic evaluation includes not only the examination of an entity's income statement, but also an analysis of the storages of productive resources utilized by the entity. Accordingly, accountants have developed a financial statement, the statement of financial position, which communicates information concerning the storages of productive resources.

The Problem Inherent in Accounting for Long-Lived Productive Resources

Traditionally, accounting has performed the information processing and reporting function by matching valuation coefficients for resource inputs, based on acquisition exchange ratios, against the revenue earned by utilizing these resource inputs in providing output. This procedure results in very few significant conceptual problems as long as resource inputs are completely utilized within a short time after acquisition. However, serious problems do arise in the situation where input resources have a long life in the sense that they aid in producing the revenues over a number of accounting time intervals.

These problems come about because information users require firms to report the results of financial transactions for abritrary intervals of time at the end of which there are many incomplete transactions, particularly with respect to long-lived productive resources. For instance, a company purchases machinery which is used for producing a given product and this machinery will be used for ten years. Accounting conventions require the results of operations to be reported annually by matching dollar inflows (revenues) against dollar outflows (expenses). However, the outflow required to obtain the machinery cannot be matched against the inflow for the year of acquisition because the inflows of future years are affected by utilizing the machinery in those years. Therefore, the accounting profession has adopted the conceptual notion that long-life productive resources represent bundles of future services, some portion of which is assumed to be consumed during each accounting period of its useful life. This implicit recognition of an allocation problem raises two difficult conceptual questions with respect to prices.

First, given that the objective is to match expenses with revenues, what should be done if the ratio of exchange for services identical to those purchased in one time interval changes in a future time interval? This raises the possibility that entities will match a different dollar expense against their revenue solely because they purchased identical services at different times. Second, how should the bundles of remaining services be valued for the statement of financial position - at historical cost to reflect the acquisition exchange ratio for the services, at some current value to reflect the assets subject to management's control at a given point in time, or by use of some other measurement base for determining the appropriate valuation coefficient?

The answers to these two related questions indicate not only the appropriate analytical interpretation to be given to income statements, but also the appropriate evaluation to be applied in analyzing statements of financial position. This point may be illustrated by considering the following examples. First, consider the situation where the ratio of exchange for a given long-lived resource increases and the price of the output produced by use of this input also rises. Matching the lower allocated original cost against current revenue will give an upward bias to the excess of receipts over cost resulting from operations. Second, consider the situation where the price of the input resource rises without a compensating increase in the price of the output that the resource is utilized in producing. As there is a normal relationship between investment in a long-lived productive resource and the rate of return expected from its utilization, it may be that it is inadvisable to replace this productive resource as it is currently utilized. However, this low rate of return on an investment may not be apparent if the lower original cost is being matched against current revenue and the resulting net income is being divided by the original cost in determining the rate of return. Only by matching the higher replacement (or reproduction) cost against current revenue and dividing the resulting operating income figure by the higher current cost will the reduced rate of return be reflected by the return on investment computation.

In recognition of these difficulties a substantial body of accounting literature has evolved consisting of proposed solutions and criticisms of these solutions. The proposed solutions include periodically determining the net present value for the firm as a whole, determining the current ratio of exchange for specific assets (either input or output exchange ratio), adjusting acquisition exchange ratios by either specific price indexes or general price indexes, and finally additional theoretical justification in support of acquisition exchange ratios as valuation coefficients. None of these alternatvies to historical cost have been found acceptable in practice, generally because of implementation problems.

Purpose of Research

A general energy systems analysis of economic activity views money payments as feedback loops to reward the recipient of such money payments; the reward being given in exchange for the economic goods and services provided. These economic goods and services are all energy manifestations because any resource input, as well as any resulting output, is the result of work and work can always be measured in terms of energy equivalent units. Therefore, the price received for a long-lived productive resource divided by the total energy equivalent of the resource inputs needed to produce that productive resource represents the average price per unit of energy used in this particular fashion. In other words, in the energy systems' analytical framework, an average price per unit of energy is determined by relating money flows with energy flows and it will vary over time in response to either changing prices for the output resources or changing productive efficiencies in using resource inputs for the production of output resources. Prices for productive resources may change because of changes in the demand-supply conditions of either the resource input market or the productive resource market, and also because of changes in the efficiency of the long-lived productive resource itself. Since the average price per unit of energy is based upon the market price of the long-lived productive resources produced and sold in the current time interval, it appears the general energy systems' analytical framework may provide an acceptable methodology for estimating the current acquisition exchange ratios to be used as valuation coefficients for financial accounting. Therefore, the problem at hand is to develop and evaluate an energy systems methodology for measuring current ratios of exchange for long-lived productive resources, previously acquired and currently utilized by an accounting entity. Evaluation shall be accomplished with respect to certain objectives defined as ends-in-view.

Methodology

This inquiry will be conducted within the philosophical framework of the scientific method as espoused by Dewey.[5] As with all inquiry, Dewey's scientific method begins with a problematic situation. A problematic situation is a disequilibrium condition within the inquirer himself which results in tensions and felt needs. The attempt to move into an equilibrium status and thus relieve tension results in inquiry. Therefore, "problematic is a property of the situation which includes, among other items, the inquirer himself--the process of inquiry results from a combination of undifferentiated facts: a yearning by the inquirer for resolution of the tension and the unidentified ability to form hypotheses and specify ends-in-view."[6]

Dewey emphasized that inquiry should always be related to reducing tensions; therefore, situations with problematic content should be expressed in terms of models that employ the means-consequence format with consequences being continuously related to ends-in-view.* This inquiry will express no particular preference for a means-consequence format for models. However, it is felt that the propositions being investigated should be expressed in a form that allows the investigator to determine whether it is true or false.* Like Dewey, this writer believes that propositions should be continuously related to the ends-in-view necessary to resolve the problem.

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*Ends-in-view may be described as expected relationships which would result in an equilibrium status being achieved and tensions being reduced.

Since Dewey's framework of inquiry takes on the characteristics of the traditional, interpreted, logical system, the test of efficiency and truth employed in this inquiry are precisely those employed to test any hypothetical model. In addition, this inquiry will stress the unity of the inquiry process. That is, no attempt will be made to partition the process into induction-deduction, rationalism-empiricism, and other such classifications. Rejection of these classification schemes emphasizes the necessity of theoretical verification by both logical reasoning and empirical correspondence between actual and predicted outcomes before any conclusions concerning a proposition's degree of warranted assertibility can be stated. In other words, it is recognized that a scientific investigation by reasoning, with no experimental interpretation, is not sufficient, and theory separated from actual doing is not realistic. Accordingly, this inquiry will emphasize the necessity of both logical reasoning and empirical investigation of propositions before warranted conclusions can be stated.

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*In Dewey's system of inquiry propositions are not true or false during the process of inquiry: they are efficient or inefficient for resolving the problem. Truth is undefined during the process of inquiry and can be employed tentatively only after inquiry stops. In other words, inquiry consists of making all sorts of judgments with regard to relative efficiency of means, the relevancy of data, the importance of ends-in-view, and so on; but for Dewey the practical aspects of truth and falsity become questions of warranted assertibility. While inquiry is in process, applicable propositions are relatively efficient or inefficient and no assertion regarding their truth is warranted. At the conclusion (defined in terms of agreement between predicted and actual consequences) of the specific inquiry and assertion about the correspondence of actual and predicted consequences may or may not be warranted.[7]

The Problematic Situation

The disequilibrium condition, the felt needs, and the necessity for further research have been examined above. In Chapter II of this inquiry these problems will be developed in greater detail. Specifically, the historical evolution of current accounting practices, with particular reference to the principal developments within man's social system which have influenced the development of the accounting component of the information-communication subsystem, will be examined. The criticisms of using acquisition exchange ratios as the measurement base for valuation coefficients will also be discussed, including a rather comprehensive summary of the debate between supporters of the use of acquisition exchange ratios and the critics of such a measurement base. The inclusion of this background information is for the following purpose: (1) to provide greater insight concerning the problematic situation; (2) to justify logically some of the underlying assumptions stated below; and (3) to describe the conceptual basis for the working propositions to be used in evaluating a general energy systems price model.

The Ends-in-View

The ends-in-view refer to the consequences necessary in order to reduce the tensions which have resulted in the inquiry. Therefore, since the energy systems price model is a proposed approach for measuring long-lived resource currency values, this writer feels it should be evaluated in light of the criticisms of previously proposed methods for accomplishing the same objective. In following this procedure, it is hoped that assertions can be stated concerning the efficiency or inefficiency of the energy systems approach in resolving the valuation coefficient conflict within the accounting profession. Accordingly, the ends-in-view developed below are based on the criticisms of other proposed methods for estimating current cost data (these criticisms will be discussed in Chapter II).

It must be explicitly recognized that accounting operations are subject to certain legal and moral restrictions. For instance, accountants are expected to render unbiased information to outside parties. Accordingly, the most frequently cited criterion for evaluating the acceptability of a particular accounting measurement is objectivity (assuming the measurement method generates data relevant to the user and is capable of practical implementation). However, before objectivity can be established as a desired quality inherent in any proposed measurement system, it must be precisely defined. "Rather than basing the definition of objectivity on the existence of objective factors that are independent of persons who perceive them, it is far more realistic to define objectivity to mean simply the consensus among a given group of observers or measurers. Therefore, objectivity is seen to be a function not only of the object being measured but also of the measurer and the measurement system used."[8] Objectivity, thus defined, exists only as a matter of degree in any event. But examination of the accounting literature reveals that if the proposed alternative measurement system involves either discounting future service potential or appraisal values, there is too wide of a dispersion of the measurer's opinions for their consensus (where consensus is some average of their opinions) to be considered objective. Therefore, any proposed method for estimating current cost must be evaluated by considering the degree of empirical correspondence between the measures generated by different groups of observers applying that same specific measurement method.

A second end-in-view is concerned with the question of the accuracy of the measurement. Here the term accurate refers to the degree of empirical correspondence between a given measurement and the ideal representation of the measured attribute of an object. Obviously, accountants strive to obtain the most accurate measures possible within time and cost limitations. The ideal measurement base for long-lived productive resources is the net present value of future potential services. One economic assertion is that a market price established in arms'-length transactions between competing parties best reflects an aggregate evaluation by purchasers of the present dollar value for the future benefits to be received as a result of owning the resource.* However, changes in the prices of long-lived resources result from many interacting factors, such as changes in the supply and demand for the various resource inputs needed to produce the long-lived resource or for the productive resource itself, changes in the overall productive efficiency of the processes which supply these resources, and changes in the ability of the productive resources to perform their desired function. Thus, any estimation procedure must be evaluated in light of how well it segregates and integrates these various related components of any given price change in determining the most accurate estimated exchange ratio.

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* The logical reasoning for this assertion is discussed on Pages 60-61.

Thirdly, the data collection and processing procedures for generating ratio of exchange estimates must be logically consistent.

Research Constraints

It is realized by the inquirer that the nature of this research effort forces inquiry to proceed subject to certain limitations. These research constraints are identified as follows:

First, this inquiry is primarily an interdisciplinary, exploratory inquiry dealing with the development of a new system of analysis which will provide greater insight concerning economic relationships. Therefore, it is probable that the inquiry will end before any of the working hypotheses attain warranted assertibility. In other words, the tentative hypotheses are formulated for the purpose of directing exploratory research; thus, the only contribution of this effort may be to clarify concepts and show the direction for future research.

Furthermore, as this inquiry is concerned with a somewhat recently developed methodology, there is a decided lack of data available for empirical testing. Therefore, most of the empirical testing may have to be simulation with hypothetical data. The data inputs necessary for operation of the general energy systems price model include:

1. The currency flow which would be received by all producers of any specified long-lived productive resource during any given time interval, assuming that all output produced by those producers during the given time period was also sold during that time interval.

2. The total quantity of resource inputs--expressed in terms of energy measurement equivalents--needed by the producers to manufacture the specified output.

3. The quantity of specified output produced with the stated resource inputs during the particular time interval.

4. The quantity of output per unit of resource input which can be produced by utilizing the specified productive resource in a given production activity.

All of this data is currently readily available except the energy flows for resource inputs. However, to answer any doubt concerning the feasibility of operational application of this methodology due to lack of data, it may be noted that extensive research is ongoing at the present time by Bruce Hannon of the Energy Research Group at the University of Illinois, Resources for the Future, Stanford Research Institute, the State of Oregon, Regional, State, and Local Growth Planning Agencies, the Energy Center at the University of Florida, and many other governmental and private research agencies to obtain the missing data. While these research efforts are primarily related to determining where energy use can be cut with the least economic pain in the event of another Arab embargo, it is precisely the same data that is needed to relate energy flows with dollar flows in making a general energy systems price model operational.

Thirdly, this inquiry is restricted to long-lived resources as there has generally been no substantial objective to the use of acquisition cost as a measurement base for measuring expenses other than depreciation. This may be due to the fact that the expirations of service value of things such as raw materials, labor, insurance, and so on are relatively close to the time of their acquisition.

The Assumptions of the Inquiry

The first underlying assumption of this inquiry is an economic assumption which may be stated as being composed of two related assertions. The first one states that productive resources have money value only because of the future services they are expected to provide. In addition, the ratio of exchange for a specified resource in a free exchange marketplace is believed to represent a fair, average aggregate of the opinion of all buyers and sellers operating in that market concerning the estimated present value of those future services. A corrollary second assertion states that two resources, identical in all respects, would command identical market prices at a given instant in time in the same marketplace. This, in turn, implies that two resources, identical in all respects except that one is more efficient in the transformation of input resources into desired output than the other, would command different money prices which would be proportional to their difference in efficiency.

A second assumption is that man performs work in order to supply goods and services for himself. This assumption is necessary to the construction of the productive efficiency and relative input transformation efficiency indexes developed in Chapter IV.

A third assumption is that users of accounting information desire financial statements based on valuation coefficients determined with reference to a measurement base other than acquisition exchange ratios. In other words, it is assumed that the most relevant or useful measurement base to be used in financial accounting is the current period's reproduction exchange ratio (or replacement exchange ratio). This particular assumption is discussed in detail in Chapter II.

The Development of the Energy Systems Ratio of Exchange Model

The energy systems price model for long-lived productive resources will be developed in two steps. First, general energy systems theory will be described in Chapter III including a discussion of ratio of exchange relationships when using an energy systems approach. In general, the discussion of this chapter is expected to provide the underlying conceptual framework necessary for relating energy flows to money flows. Second, in Chapter IV, the energy systems concept (basically the relationships between energy flows and money flows) developed in Chapter III will be applied to the specific problem at hand: development of an energy systems price model for estimating reproduction or replacement ratios of exchange for long-lived productive resources. This model may be mathmatically expressed as follows:

$$P_{est} = \frac{q_i p_i}{E_i}$$

Where: P_{est} = the estimated price per unit of input resource expressed in terms of constant quality energy heat units;

q_i = the quantity of output i produced during a given time interval;

p_i = average price per unit of output i during the given time interval;

E_i = the energy equivalents of all the resource inputs utilized to produce q_i.

The Evaluation of the General Energy Systems Ratio of Exchange Estimation Model

As stated above, the purpose of this inquiry is twofold: (1) to develop a methodology for estimating replacement exchange ratios based on energy systems concepts and (2) to provide a preliminary evaluation of the efficiency of such procedures in resolving the conflict, among accountants, concerning long-lived resource accounting procedures. Therefore, in Chapter V, the general energy systems model, developed in Chapter IV, will be evaluated by way of the tentative, working hypotheses stated below. These general hypotheses are stated and discussed in greater detail as follows:

1. *The conceptual framework of the general energy systems approach is logically consistent.* In order to become widely accepted, any theory must be logically

consistent, both internally and with related theories which are accepted. Accordingly, the following two subhypotheses may be stated with respect to this first general hypothesis:

a. *The general energy systems ratio of exchange estimation model is internally consistent.*

b. *The resulting price estimates are logically consistent with the ratios of exchange expected in light of currently accepted economic price theory.*

2. *The general energy systems approach provides accurate estimates of the current reproduction (or replacement) cost of a specified long-lived productive resource.* One objection to the use of current market prices for new productive resources (designed to perform a similar function that an older resource is currently providing) as a measure of the current cost of an older resource is that the newer style is not the same as the older. The newer resource is produced using current technology for transforming resource inputs into outputs and such production techniques may be different than the technology existing at the time the older style was produced. Furthermore, the newer resource may be more efficient in performing the function it is purchased to perform than the older resource. Both of these factors will interact with all other factors which cause demand and supply to change in determining the market price of the new resource. Therefore, in determining the most accurate exchange ratio which can be used as the

valuation coefficient for an older resource, it is necessary to be able to segregate that portion of the difference between the current market price of a newer resource and the acquisition price of the older resource that is caused by the differences in both the efficiency of producing the resources and the ability of the resources to perform their designed function. Accordingly, in evaluating the energy system's measurement procedures it is necessary to examine the following subhopotheses:

a. *The energy system's approach provides procedures for identifying and segregating estimates of that portion of a change in the price of a productive resource that is caused by changes in the efficiency of producing the resource.*

b. *The energy system's approach provides procedures for identifying and segregating estimates of those portions of a change in the price of a long-lived resource which are the result of changes in the input transformation efficiency (i.e. the ability of the resource to perform the tasks it was designed and acquired to perform).*

c. *There is a high degree of empirical correspondence between an energy systems estimate of the current replacement cost for a long-lived productive resource and the observed ratio of exchange for this identical resource in a competitive market transaction.*

3. *The energy systems approach for estimating current replacement or reproduction cost can be made operational such that there is reasonable statistical correlation between the estimates provided even when different groups of observers apply the measurement procedures in generating estimates.* This general hypothesis is explicitly focusing on the objectivity end-in-view. In reality, it is asking if the energy system's method of generating current ratios of exchange can be made operational in such a fashion that all C.P.A.'s would generate approximately the same estimates given a specific fact situation. This particular question is a strictly empirical inquiry which requires examination of the dispersion of current cost estimates for a specified resource when different groups of C.P.A.'s are provided with identical information and told to estimate current cost using general energy systems procedures.

NOTES

1. Kenneth Boulding, Economic Analysis--Volume II (New York: Harper and Row, 1966), p. 25.

2. Ibid, p. 26.

3. Ibid.

4. Howard T. Odum, Environment, Power and Society (New York: Wiley-Interscience, 1971), pp. 174-176).

5. John Dewey, Logic, The Theory of Inquiry (New York: Holt, Rinehart, and Winston, Inc., 1938.

6. Carl T. Devine, "Book Review--Development of Accounting Thought by H.T. Deinzer," The Accounting Review (January 1966), p. 189.

7. Ibid, p. 190.

8. Yuji Ijiri and Robert Jaedicke, "Reliability and Objectivity of Accounting Measurements," The Accounting Review, (July 1966), p. 476.

CHAPTER II
DETERMINATION OF VALUATION COEFFICIENTS--A CRUCIAL PROBLEM FOR ACCOUNTING

Before continuing with a detailed examination of the problematic situation, it is necessary to provide definitions of potential measurement bases commonly encountered in accounting literature. Measurement in this inquiry refers to the assignment of valuation coefficients to non-homogeneous resources for the purpose of making them additive by expressing their quantities in terms of a common unit of measurement. The term measurement base will be used to refer to the particular exchange ratio concept employed as the valuation coefficient necessary to the measurement process. It should be noted that this list of measurement bases includes both those which are actually in use for current financial accounting purposes and those which have been proposed for future implementation.

1. Historic or acquisition cost. Historical cost represents the dollars used to record the original transaction with outside persons or accounting entities in the acquisition of economic resources. This is the measurement base currently accepted in accounting practice with some exceptions in specified situations.

2. Price-level restatements or stabilized accounting. This is historic cost, as defined above, restated to eliminate the effects of general inflation or deflation (i.e. to express the common denominator currency in units of equivalent purchasing power) on the financial statements.

3. Reproduction or replacement cost. This is the cost in current dollars of reproducing an asset presently held. The new asset may be identical in all respects to the older asset or it may be similar only in that it can be used for accomplishing the same purposes as the older resource.

4. Forced sales price. This is the amount which can be obtained by selling a resource in the firm's possession under circumstances such as bankruptcy proceedings.

5. Current cash equivalent. This is the price obtained in the regular market place in the normal course of business over a reasonable period of time. It is sometimes referred to as the quoted market price or the orderly liquidation value.

6. Present value of future benefits. This amount is the discounted flow of net cash benefits traceable to the resource. Generally, the net benefits are very difficult to measure precisely, but in perfectly competitive markets the discounted present value of net cash receipts

is assumed to be equal to the current selling price. Furthermore, reproduction cost is assumed to approximate the present value of the cost necessary to recreate the resource.

The Problem in Historical Perspective

Historical studies indicate that pre-double entry bookkeeping evolved primarily as a means of accounting for resources. "Stewards kept accounting records not for the entity's sake, but for their own use in order to control the resources for which they were responsible. There was no clear distinction between profits and capital and thus no tradition of precise income determination to impose a discipline on asset measurement and amortization."[1] In these historical periods, the manager of a venture was in most cases the owner and debtor-creditor relationships rarely existed. Ventures generally were short-lived, and as such, management's judgments were subject to evaluation at the end of a given venture when total liquidation occurred.

As exchange relationships became more complex and more frequent, merchants felt the need to periodically summarize the results of their trading performance. Thus, income calculation became a major bookkeeping problem and the double-entry system evolved. Consequently, accountants developed a mechanism "to replace unspecified, subjective views of income with a quantitative, uniform calculation which made gross profit essentially the difference between buying and selling prices."[2] This unsophisticated accounting system worked reasonably well during that period of time when most business ventures were of a trading nature and there was not extensive separation of ownership, management, creditors, laborers, and customers.

With the advent of the industrial revolution, accounting problems became increasingly complicated relative to those encountered in a mercantile, trading era. Manufacturing facilities required large aggregations of capital which could be acquired only by many people pooling their resources and this sometimes resulted in widely dispersed ownership. Moreover, these widely dispersed owners began to show a tendency to hire professional managers to operate their businesses. Furthermore, the large capital requirements led to a great deal of borrowing and lending activity. Thus, the need arose for information which would enable creditors to evaluate the security of their loans and owners to evaluate the ability of managers.

In addition, the need to acquire long-lived resources for manufacturing operations encouraged the advent of the corporation to insure operating continuity. This, in turn, further accentuated the need for periodic evaluations of managerial activity and business resources. Moreover, periodic reckonings were legally required as a prelude to dividend payments. As stated by Littleton, "attempts to determine the income earned during a particular period of time for an entity with an indefinite life naturally led to a system of accrual and deferrals. This meant the use of goods and services, not merely their purchase, created expense; also sales rather than cash collections signalled the earning of income."[3]

During the late 1800's, a series of court decisions, reinforced by statutes, required dividends to be declared only from earnings. In response, accountants developed very detailed resource measurement and depreciation methods in order to make the necessary distinction between capital and income. Even so, income calculations still showed little sophistication, precision, or consistency. Moreover as it became accepted that the computation of the annual income available for dividends was a primary accounting task, conservatism became the dominant accounting principle to which others were subordinated when they came into conflict.

> Systematic understatement of asset values was thought necessary to offset managerial manipulation and to offer bankers, who were the most influential group of statement users, security against inflated collateral values. This concept was strengthened by over thirty years of steady price declines following the War Between the States.[4]

During the early twentieth century, several corollary accounting principles evolved out of reference to conservatism, the most important of which was the going concern concept. "This concept implied an obligation to maintain plant and equipment resources intact during a company's indefinite existence by requiring that provision be made for recovery of the capital invested in the resources before dividends were paid."[5] Furthermore, it brought with it the idea that long-lived resources should not be revalued unless such changes reflected the exchange ratio to the going concern. This made historical cost both conservative (i.e. the resource must be worth to the accounting entity at least what the entity was willing to pay for it) and convenient (i.e. easy to verify the original transaction price). In other words, "it became common for original exchange ratios to be defended in terms of either the historical nature of accounting or the need for conservation rather than in terms of the need for objective evidence of the economic sacrifice the entity has made currently by using productive resources for its particular operations."[6]

These concepts of conservatism coupled with the going concern notion* were greatly strengthened by the appearance of the income tax laws. Since the tax was on income, not on wealth, there had to be an objective, legally authorized way to determine a year's income. "By defining taxable income as the excess of cash receipts over cash payments, these early tax laws made it necessary to measure income separately from the capital which generated it. Therefore, from the first, a realization rule was an integral part of income taxation and any increase in wealth had to be confirmed by some event or transaction, normally the receipt of money, before profit was said to exist."[7] This intent was explicitly made clear when the courts defined taxable income as "not a growth or increment of value in the investment, but a gain, a profit, something of exchangeable value proceeding from the property, severed from the capital...."[8] Thus, the realization rule emphasizes the disposition of assets or their separation from the firm in an exchange transaction before changes in ratios of exchange may be recognized and this view remains the dominant one in accounting and law today.

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*Which resulted in long-lived productive resources being measured in terms of original exchange ratios and these historical costs being assigned to time intervals for purposes of being matched against revenue in order to determine the accounting period income.

Court decisions in both the dividend payment area and the income tax area supported the idea that resources should be valued based on acquisition exchange ratios until they result in an effective addition to the wealth of the holder as evidenced by a severance of gain from capital. Accountants gradually modified their concepts to coincide with these legal concepts as the "legal notions were somewhat supported by the doctrine of conservatism coupled with an incomplete going concern concept."[9] This modification was greatly hastened by the severe inflation of the 1920's being followed by severe deflation, resulting from economic collapse, in the 1930's. The overall effect of such an economic climate was to give rise to the conclusion that currency exchange ratios for resources "have no more real tangibility than the thinnest of thin air...thus the chief functions of the accountant must relate to past transactions or current binding contracts and other factors must be kept to a minimum."[10] In other words, "every fact recorded in the financial statements must have resulted from accomplished financial transactions modified by an attempt to assign to proper time intervals all revenue and expenses."[11]

However, some accounting theorists took issue with this conclusion and accepted the economist's concepts of income and resource valuation coefficients. For instance, John Canning proposed a theory of resource measurement transplanted from economics and contended that the proper valuation coefficient of any resource should be based on the present value of expected benefits.[12] Furthermore, changes in valuation coefficients (resulting from changes in expected future benefits) affect income and this effect should be recognized in the accounts as soon as reliable estimates can be obtained. "This view of resource measurement and income determination has proved more theoretically defensible and consistent than that of the traditional accountant as evidenced by the fact that accounting theorists since the 1950's have tried to reconcile economic and accounting concepts in order to give accounting a sound conceptual basis and make accounting techniques consistent with what is now considered good theory."[13] In the overall picture, these efforts have not received a very warm reception, even though major disagreement concerning resource management and income determination have continued to plague the accounting profession.

The accountant's professional relationship to his client and the public may be one of the most significant reasons why accounting practice has not evolved consistent with economic theory.

> Not being as vulnerable to third party liability the economist is less inclined to seek protection in such doctrines as objectivity and conservatism. Accordingly, the greatest difference between the accounting and economic approaches in this area is the economist's willingness to recognize the effects of inflation, holding gains and losses, increments to goodwill, and other exchange ratio changes as they accrue. He would insist on measuring a person's "well-offness" at the moment when exchange ratios change, not at the time of an external transaction which provides undisputable evidence of a change.[14]

Currently Accepted Accounting Procedures for Recording and Reporting Transactions Dealing with Long-Lived Resources--A Brief Summary

Examination of some of the currently accepted accounting procedures with respect to long-lived productive resources provides some evidence which indicates the overwhelming influence that legal considerations (which have evolved in the dividend payment area, the income tax area, and the third party legal liability area as discussed above) have exerted over the development of the theoretical foundation of accounting.

The principal valuation coefficient in accounting is the acquisition exchange ratio (or historic cost) which is the original money (or money equivalent) investment necessary to acquire resources in market transactions. However, there are some exceptions to this rule such as lower of cost or market for both inventories and temporary investments. Also, there are distortions of this cost concept which result in either the income statement or the statement of financial position being made more accurate at the expense of the other--one example is an inventory flow assumption such as LIFO versus FIFO. Moreover, there is implicit acknowledgement of changes in valuation coefficients from acquisition exchange ratios without the formal recording of the changes through the use of footnotes and parenthetical comments to financial statements, as well as management comments concerning the entity and its operations.

Gains (from holding resources) are generally recognized and reported only to the extent that they are realized in market transactions, but losses are sometimes anticipated by writing down resource valuation coefficients before disposition. Furthermore, the actual gains and losses realized on the disposition of long-lived productive resources are generally reported in a different manner from ordinary sales of product or service because the amounts realized and reported in the time period of disposition may include exchange ratio changes that have occurred in a prior period or periods.

Criticisms of Current Practice

Criticism of current accounting practice with respect to long-lived resources generally is concerned with the determination of their proper measurement base. Moreover, this particular controversy has implications for both the statement of financial position and the income statement. Briefly stated, the statement of financial position attempts to convey information to statement readers concerning the stocks or storages of various resources controlled by management at a given instant of time (these quantities being measured in terms of a common unit of measure--dollars), as well as the claims (in terms of debt or equity) against these resources. Since the heterogeneous physical resources are expressed and combined in terms of currency units, the resulting dollar totals indicate resource storages only indirectly by virtue of the fact that the expressed dollar totals represent command on all goods and services by way of the price mechanism. However, as the acquisition exchange ratios for resources are continually changing, a sum of measurements based on acquisition exchange ratios, each from a different instant in time, conveys inaccurate information converning the valuation equivalents of the resources available to management at a specific point in time. The only solution which would both correct the inaccuracy and allow resources to continue to be measured in terms of currency is to determine the valuation coefficients for all resources in terms of the exchange ratios prevailing at the same instant in time. In other words, the exchange ratios to be used as valuation coefficients for measuring the resources owned must not be out of time relationship with one another.

The income statement attempts to convey information concerning the results of operations for a specified time interval. The utilization of a long-lived productive resource is reflected in the net income computation by way of the depreciation charge. Depreciation is an explicit recognition that a time will come when it will no longer be worthwhile to utilize a unit of an entity's long-lived productive resources. The unit may be no longer useful to the owner because of the physical deterioration of the unit, because of a change in demand for the output of a facility, or because a technical improvement of one kind or another has made the unit obsolete. But the fact remains that the services of long-lived productive resources are almost always eventually consumed. Depreciation accounting then is the effort to charge the cost of such services--like other applicable expenses--to the revenues earned during a given accounting period in a systematic, equitable manner.

> In other words, there are two independent aspects of the cost allocations arising from depreciation. The first is the timing of the cost recoveries which refers to their distribution among accounting periods and is a function of the depreciation method employed (straight-line, and so on). The second is the total dollar amount allocated which is a function of the choice of measurement base (historical dollar cost, replacement cost, and so on). And neither of these is related to a third aspect which is the estimate of a resource's useful life.[15]

Applying the currently accepted accounting procedures for associating effort with accomplishment in accounting for long-lived productive resources results in a measurement rule which requires the cost associated with the utilization of these resources to be determined by allocating the original monetary cost to accounting time periods. However, the ratios of exchange for all the stored resources change over time; thus, the accounting assumption that costs somehow attach like barnacles to various long-lived resources obscures the association of sacrifice and benefit that is considered relevant for proper decisions and actions. For example, if the replacement cost of a resource has risen since the time of its acquisition, the amount allocated certainly does not represent the current cost of resource utilization. Income determined by using such a measurement basis may not properly communicate the change in economic position resulting from operations since it is determined by matching revenue based on current sales prices with cost based on past period prices. Thus, conventional accounting treats the effects of price changes for long-lived productive resources as though they were a component of operating profits or losses which they are not. Expressed another way, with current accounting procedures, income arises from two related, but to some extent independent, sources: (a) the margin between the actual selling price for the output and the current acquisition of the input resources needed to produce the output; and (b) the so-called gain or loss arising from a change in the price of input factors between the time of their acquisition and the time of sale of the output produced by utilizing these inputs.* The first source is considered an operating result over which management can exert considerable influence. The second is considered a holding result over which management can probably exert little, if any, control, although, it may be said, management should anticipate such price changes. In any event, it appears inappropriate to combine these two sources into one operating figure as is now done. It is felt that more meaningful accounting information can be communicated if these two sources are segregated and analyzed separately.

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*This second source is generally referred to as a holding gain or loss. Expressed another way, holding gains and losses represent changes, over a time period, in exchange ratios of resources and liabilities held during that period. This concept implies that a base amount can be compared with an adjusted exchange ratio either at the end of the period or during the period, if disposal takes place, in order to measure a change in value.

For over fifty years debate has continued between steadfast defenders of acquisition exchange ratios as valuation coefficients and equally adamant advocates of the use of some current cost concept. In general, the arguments have centered on whether the above described distortions of accounting information are significant enough for concern. In other words, the accounting problem being debated seems to be concerned with a single question: should the valuation coefficients reflect current exchange ratios (as opposed to acquisition exchange ratios) in light of the fact that such a procedure would require explicit recognition both in the accounts and in financial reports of changes in ratios of exchange without the tangible evidence of a specific market transaction? In dealing with this question, there appear to be two areas of critical concern: should valuation coefficients, based upon current acquisition exchange ratios, and the resulting holding gains and losses be recognized in the accounts and reported in the financial statements; and how should current acquisition exchange ratios be measured? The arguments of both sides of the debate will be presented in the following sections.

Recognition and Reporting of Current Acquisition Exchange Ratios Including the Associated Holding Gains and Losses

The debate concerning the recognition and reporting of acquisition exchange ratios has generally centered around the following briefly summarized points:

1. Some accountants feel that "the cure is worse than the ailment as current costs are not objective."[16] That is, historical cost is relatively easier to objectively verify than current cost; "the fact that current cost, in some instances, is very difficult to ascertain is perhaps the greatest objection most accountants have to it."[17] This objection to current cost clearly illustrates the influence of potential third party legal liability over accounting. It is feared that the use of exchange ratios which are not absolutely verifiable will open the door for manipulation and charges of collusion. Advocates of a change to current cost counter this objection by stating "even historical cost is only a tentative figure... accounting deals largely with judgments and estimates, not with certainty. Values are always more or less conjectural and unstable."[18] Furthermore, it is asserted that periodic income measurement under the best of conditions is no more than a good guess:

> The argument that recognizing appreciation would call for recording unrealized profits is not correct, since all accruals are based on the unrealized transactions in the same sense. Furthermore, appreciation can in many instances be estimated more accurately than depreciation or decline in value due to deterioration or handling.[19]

2. It is stated that the same problems for allocation of cost to accounting periods remain. For instance, is depreciation to be determined

   a. By overall industry experience?

   b. By traditional straight-line method as applied to production units or time periods bolstered by engineering estimates of the total remaining service potential as reestimated periodically?

   c. By any of several practices permitted by the income tax laws or government regulatory bodies?

Advocates of current cost would properly respond that this objection has nothing whatsoever to do with the problem at hand. The problem of allocation of service potential to accounting periods must be equally as difficult, and somewhat abritrary, regardless of which measurement base is used. In other words, it is a problem independent of the measurement base question.

3. Defenders of historical cost also object to current cost on the grounds that historical cost more clearly results in the purposes of accounting being fulfilled. One point frequently noted is that accounting records should be

maintained in such a manner that income which is legally available for dividends is reflected. If this purpose is accepted accountants are forced to adopt the legal notion of realization and its corollary principle that the measurement base shall not be changed from the acquisition exchange ratio (except to reflect loss of service potential) until such time as an exchange transaction with an outside party occurs. Accountants must accept this result because court decisions and statutes have generally forbid cash dividends to be paid out of retained earnings arising from either unrealized appreciation in the value or the revaluation of long-lived resources. The obvious response to this objection is that computation of legal dividend income based on acquisition exchange ratios can be accomplished concurrently with the computation of financial income based on current exchange ratios similar to what is now done for income tax purposes.

4. Some accountants feel that the use of acquisition exchange ratios is so bound up with the evolution of double-entry bookkeeping that radical departures from it, such as current costing, could threaten an integration of real and nominal accounts. And this integration is felt to be far more important than the particular valuation coefficients which are being related to individual resources and liabilities. In other words, historical cost is the only measurement base which requires, as an integral part of its

measurement procedure, that every actual change in the dollar amounts associated with resources of an entity be recorded by relating inputs and outputs. This relating of inputs and outputs is necessary so that original cost can be traced and identified; thus, it is an automatic control feature which may be missing with current cost. These accountants generally feel footnotes and parenthetical notations are an effective means of providing information concerning exchange ratios differing from acquisition cost. The response to this objection is to ask the question: are accountants willing to sacrifice the accuracy of currency measurements for resources and be content to present rather artificial amounts in financial statements, despite the conceptual problems associated with justifying inconsistent theory, in order to mathematically tie the income statement to the balance sheet?

5. It is noted that historical cost provides the background of the story of the way in which management has functioned by reflecting only actual transactions. Moreover, "a primary objective of accounting is the protection of resources (stewardship) and this means the primary concern is with the allocation of real and actual cost to accounting periods and output, and by no stretch of the imagination can current cost be relevant to such a process."[20] A current cost advocate would respond to such an objection by stating that in large businesses the profitable use of

resources is more important than either their physical protection or a history of their acquisition. And for financial statements to provide relevant data about a firm whose ownership interests are constantly changing hands requires the fairest and most objective possible presentation of current financial events. Furthermore, if there are such things as real and actual cost of production, they must surely be the cost in the current competitive situation. The exchange ratio paid for a resource at some time in the past certainly has no current economic significance except possibly for evaluating management's stewardship. Thus, if one of the objectives of accounting is to record and report accurate information with respect to present financial condition, then it follows that accountants should adopt a measurement base which furnishes current and up-to-date information.

6. In any list of objections to current cost the concept of conservatism arises. Simply stated, this principle implies that no profits should be anticipated, but all losses should be provided for. This notion appears to be a carryover from the early days of accounting when stewardship was the prime bookkeeping motive and most business ventures were short-lived. As stated by Chatfield:

> In this setting, where the main accounting responsibility was protection of

> resources, conservatism was natural and rational. The steward would be foolish to raise expectations which might not be borne out by subsequent events and no one is misled so long as ownership interests were not exchanged. However, a shift in emphasis during the 1930's toward the income statement caused problems in the application of conservatism as profits, as well as asset values, had to be stated conservatively. This is much less consistent a process than resource measurement conservatism. For instance, reducing valuation coefficients when current market prices fall below original cost reduces current income but may inflate future income.
>
> Thus, conservatism strengthens objections to departures from acquisition exchange ratios in order to discourage manipulation for smoothing income and creating secret reserves.[21]

Current cost supporters respond to the conservatism objection by pointing out that it is important not to confuse conservatism with downright understatement when passing judgment as to which procedure is the most advisable.

7. Some advocates of current cost have justified their position in light of rampant inflation (which has been characteristic of the world economy since 1946) on the grounds that steady increases in prices have the effect of impairing stockholder's equity and encouraging the creation of secret reserves. Defenders of historical cost have interpreted this to mean that demand for current cost is based on the premise that it is not only the duty of

management to keep intact original investment in dollars by allocating historical cost to expense as the resource is physically utilized, but it must also maintain the real capital invested, measured in terms of productive capacity and present price level, so that there will be sufficient recovery of dollar cost to allow full replacement of productive capacity in the future. This conclusion raises all sorts of problems with respect to current cost.

First, it is argued that the cost of using long-lived resources has little significance in the policy for pricing a firm's output. That is, selling prices are not determined by the addition of a profit percentage to cost (except possibly in the case of a regulated industry). In other words, it is being noted that demand is an important element in the determination of selling prices since all companies must compete for the consumer's dollar, regardless of how high their cost may be. Supporters of current cost will agree that cost increases do not always lead to higher sales prices of output as the cost of an activity does not give it value, rather, it is the value of the results of the activity that justifies the incurrence of costs. However, "one cannot deny that in a highly competitive industry a large proportion of the losses is due to the failure to keep dependable cost."[22] A firm whose "management is ignorant of its actual cost is a dangerous competitor only until the firm has lost a considerable portion of its capital through pricing below cost."[23] Furthermore, advocates of current cost do not completely agree that cost does not influence selling prices. They agree such may be true in the short run under conditions where the size of facilities cannot be easily altered and demand conditions are expected to be the most important variable influencing the selling price of output. However, this is not true if the time interval is sufficiently long for quantity of output to be altered. Therefore, to say cost has little influence on price is to confuse short period analysis with long period analysis. Moreover, insofar as there is any relationship between selling prices and cost of long-lived resources, it tends to be between selling prices and current cost (because these would be the cost incurred either by new producers entering the industry or by the old producers who are replacing facilities). In other words, the conclusion is reached that it is only by "considering current cost that decision-makers are able to proceed intelligently in making long-run decisions as to which products should be concentrated upon and which methods and processes of production should be followed."[24]

Secondly, defenders of acquisition exchange ratios argue that a firm may not wish to produce the same output or use the same resources in the future, thus, there is no need to provide for replacement. Supporters of current cost concepts would also realize that on many occasions the current "use value" of resources to the accounting entity which owns them may be lower than the current replacement cost* and that if such a condition continues the productive resources will not be replaced at the end of their useful lives. In other words, the current replacement cost does not necessarily represent the value of resources to the going concern unless the entity is continuing to acquire such resources at current cost. However, the question of importance to the accountant is how to measure the costs of producing the output that is actually being produced currently. In other words, in providing information concerning the present use of resources the only relevant amounts are the costs today of producing the output actually being produced; "to say that the firm may produce different output--or the same output differently--in the future raises questions concerning the reorientation of the business objectives of the firm which are not related to the topic of inquiry here."[25]

Thirdly, it is pointed out that full recovery of replacement cost would require a knowledge of what a resource will cost at the time of its replacement, and this is certainly a matter of speculation. Current cost advocates respond by noting that adequate funds for replacement of physical resources will not be a guaranteed result of using current acquisition exchange ratios as valuation coefficients. For example, if prices are in a long-term upswing the sum of each year's current cost over the life of a long-lived resource will not equal the cost of replacement in the last accounting period the resource is used.

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*According to economic theory when value exceeds current reproduction cost under conditions of perfect competition additional units will be built. The output of additional supply reduces the net return of all units (value declines) and the cost of producing additional units may rise. These two influences will continue until value equals reproduction cost. If reproduction cost exceeds value similar adjustments in the opposite direction take place. However, there may be sustained transition periods when there is a divergence between the two.

Finally, it is noted that the function of accounting is to allocate the cost of resources as equitably as possible against the revenue produced by utilizing these resources and this problem is quite different from the problem of financing the replacement of resources. In response, it is stated that most current cost supporters do not advocate maintenance of real capital as an end itself. Rather, it is noted that business prudence requires accounting methods which report cost and profits as accurately as may be determined given the practical constraint of the cost of information versus the benefit from having it. But the methods of providing accurate accounting data will not necessarily treat related problems as separate and distinct. In other words, the fact current costing may have financing implications should not detract from its usfelness in helping to solve financial reporting problems.

8. Perhaps the strongest conceptual objection to current cost is found in the notion of relevance. Simply

stated, the area of concern is why it is necessary to give up "objectivity" in external reporting for relevance and accuracy when accountants do not seem to know what information statement users think is relevant for their evaluations. However, the response to this criticism by current cost advocates represents the strongest conceptual case for a current cost measurement base. This response can be summarized as follows:

a. Current cost represents an estimate of the amount it would cost today to obtain the same or equivalent bundle of services; therefore, it "represents the best measure of the current economic sacrifice incurred by the firm when the resources inputs are utilized in earning the current revenue."[26] Moreover, as all the costs would be computed on the basis of current economic exchange ratios, the "matching of current revenue with current costs will be more meaningful because the decisions formulated therefrom would be made on the basis of present economic data rather than past data."[27]

b. The activities of an entity can be segregated into two basic parts--operating and holding. Operating results stem from the sale of goods and services and may be defined as the difference between the selling prices of the output and the cost of producing the output, both measured in current dollars. The results of holding activities come about because of changes in the exchange ratios of resources which are the inputs needed to produce a particular output. As currently reported, business income may be composed of both of these elements, although the primary objective of most ventures is to sell a product or service and make a profit while doing so. As income from holding activity is apt to be fortiutous and unpredictable (because it comes about by factors largely beyond managerial control such as general price level movements, changes in exchange ratios resulting from technological advances, changes in tastes that affect demand for the firm's product, and alterations in factors affecting the supply of items held by the firm), such income needs to be segregated from operating results if the reported financial statements are to be interpreted meaningfully.

> Indirect incorporation of holding gains and losses into net income and misstatement of the exchange ratios for resources under management control may lead to distortion of decision making if economic decisions are based solely upon analysis of financial statements. Current costing minimizes this distortion by allowing separate analysis of holding operations and operating results.[28]

Thus, the use of current cost in the matching of cost against revenues would explicitly show the results of each of these two activities. Moreover, "the holding gains and losses would be recognized in the accounting period when the change in value occurs rather than in the period when the asset is sold."[29]

c. As noted above the "summation of current exchange ratios for resources is more meaningful than the addition of acquisition exchange ratios, which represent cost from different time periods, because such a sum will more closely indicate the physical quantity of various resources and their current economic significance."[30]

d. Having the resources owned, as well as an accounting period's expenses, measured on a "current basis would make rate of return on investment computations more meaningful."[31]

e. If all firms consistently reported current values interperiod, interindustry, and interfirm statement comparison would be more meaningful.

f. Current cost information is vital to proper management planning and evaluation. For example, if current exchange ratios have increased greatly it may be to the advantage of the owners for management to revise its maintenance and repair policy in order to extend the service life of present equipment, particularly if output selling price increases have not matched or exceeded cost increases. Also, it is beyond doubt that current exchange ratios are of prime importance in all property insurance matters. Moreover, in financing by bonds and other credit instruments it is imperative that the current exchange ratios of the long-lived resources be recognized, "because not only would the borrower be placed at a disadvantage if this were not done, but also a rather awkward situation would be presented in the balance sheet if the liability were for a sum greater than the cost of the property pledged as security."[32]

Examination of the debate between defenders of an acquisition exchange ratio measurement base and advocates of a current ratio of exchange concept, even in a briefly summarized form, enables the investigation to gain more explicit insight into the problem. These eight points of conflict can be summarized in terms of two basic considerations. The first indicates the defenders of acquisition exchange ratios strongly feel that accounting data must be objective (statistically verifiable in the sense that different groups of measurers will determine nearly identical measurements) in order to avoid third party legal liability as that concept has evolved via case law. The objectivity argument has been the roughest obstacle for the measurement base concepts previously proposed by advocates of current cost to overcome. Therefore, the logical conclusion is reached that many of the conflicts described above will cease if the measurement procedures can provide a methodology for determining objective measurements of both current acquisition exchange ratios and the associated holding gains and losses. The above reasoning then provides the conceptual justification for the tentative general hypothesis summarized as follows:

The energy systems approach for estimating current replacement or reproduction cost can be made operational such that there is reasonable statistical correlation between the estimates provided, even when such estimates are made by different groups of measurers (i.e. such operational procedures provide objective estimates of current acquisition exchange ratios).

On the other hand, the second consideration being debated in the points of conflict, which were summarized above, may be stated as follows: does current cost in the financial statements provide the most useful information given the specific sets of users and the decisions they address themselves to when using the reported financial information? Logical reasoning, comparing the difference between the conceptual ideal of what information should be conveyed by the statement of income and the statement of financial position versus what information actually appears to be conveyed (discussed in Chapter I), suggest information based on current acquisition exchange ratios must be more useful. Hence, the justification for the assumption, stated in Chapter I, that data based on current cost data provides the most useful information to statement users.

It was necessary to state this assertion in the form of an assumption because the scientific method of investigation requires empirical verification before the results of inquiry can attain a "warranted assertion" status. Empirical verification of such a hypothesis would require an examination of the motivational-behavioral responses of the users of financial statement data to that data, and this type of inquiry is beyond the scope of the current investigation.

In summary, it must be stated that no warranted conclusion can be reached concerning the propriety of recognizing and reporting current acquisition exchange ratios until the "usefulness to users of financial data" question can be empirically resolved. However, it does appear that a substantial portion of the objections to a current cost measurement base concept would cease provided a methodology for determining objective measures of current acquisition exchange ratios can be obtained. Therefore, this inquiry will be concerned with an energy systems methodology for measuring current replacement or reproduction cost.

The Measurement of Current Acquisition Exchange Ratios

The problem of measuring current acquisition exchange ratios for resources is essentially statistical in nature. In determining which modified measurement base is to be applied, it is necessary to analyze the statistical properties of various accounting numbers. In simple terms, what is desired is a measurement base which will provide the most accurate estimate possible of the current exchange ratio for acquiring the services consumed during the operations of the current period. Therefore, what is desired is an estimate of either reproduction cost or replacement cost. However, as stated above, accountants desire a measurement methodology which provides objective measurements in order to reduce the possibility of third party liability.

Therefore, this inquiry will emphasize the development of a logically consistent methodology for estimating statistically objective or verifiable, as well as accurate, estimates of current replacement or reproduction cost for resources owned by an accounting entity. This objective is consistent with the American Accounting Association's Committee on Concepts and Standards-Long-Lived Aspects recommendations as evidenced by the following statement:

> The current cost of obtaining the same or equivalent services should be the basis for valuation of assets subsequent to acquisition. Where there is an established market for assets of like kind and condition quoted acquisition prices may provide the most objective evidence of current cost. Where there is no established market for assets of like kind and condition, current cost may be estimated by reference to the purchase price of assets which provide equivalent service capacity. The purchase of such substitute should be adjusted for differences in operating characteristics such as cost, capacity, and quality. In other cases, adjustment of historical cost by the use of specific price indexes may provide acceptable approximations of current cost. Appraisals are acceptable only if they are based on the above methods of estimating current cost. Whenever there is no objective method of determining the cur-

> current cost of obtaining the same or equivalent services, original acquisition cost should continue as the basis for valuation.[33]

The techniques suggested for obtaining estimates of reproduction or replacement cost include the use of appraisals, the use of current market prices, and the use of specific price indexes. There are two objections to the use of appraisals in obtaining current cost estimates. Perhaps the stronger of the two is the subjective judgment inherent in the appraisal process. Rarely, if ever, will two independent appraisers establish the same dollar amount as the replacement cost of a given productive resource and sometimes the difference can be substantial. Another problem is the high cost of obtaining appraisals, particularly in terms of the benefits of having current cost versus the cost of obtaining them.

The use of market prices for obtaining replacement exchange ratios may be justified as follows: a long-lived productive resource is valuable because of the future services which it will render; furthermore, the subjective process of discounting involved in the translation of future benefits to present exchange ratios precedes the exchange activities carried on by buyers and sellers who enter the market. Since the exchange ratio resulting from market activity represents the collective judgment of all the users of a particular resource concerning the present currency worth of the future services, market prices implicitly provide an objective estimate of the net present value of the resource.* Such an argument is undoubtably correct provided similar resources, of similar age, in similar condition are actively traded in an established market. However, very little research has been done concerning the availability of such market data, and that which has been done has indicated a lack of available information of this type. Therefore, more extensive empirical investigation is necessary before any conclusions are warranted.

A third method generally suggested is the use of specific price indexes to adjust the historical cost of specified resources to their current cost assuming such resources are new. This method is analogous to the use of market prices, except that it requires only that resources capable of similar uses are currently being produced. The objections to the procedure have centered mainly on three areas. First, any economic price index is constructed by some weighting process whereby quantities are held constant and prices are allowed to vary. There are substantial questions concerning the accuracy of any price index when its construction is based on the arbitrary selection of a set of weights. For example, consider the following situation:

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*This discussion provides the logical justification for the assumption stated in Chapter I that market prices approximate the discounted flow of net cash benefits.

	Beginning of Time Interval	End of Time Interval
Wheat	50 bushels @ $2.00 per bushel	80 bushels @ $2.50 per bushel
Corn	100 bushels @ $ .50 per bushel	50 bushels @ $1.00 per bushel

Constructing a price index for wheat and corn using beginning of the period weights shows prices have increased by 50 percent; however, the same index constructed using end-of-the-period weights shows prices have increased by about 35 percent. Which is correct? Secondly, there is a question concerning how specific a given index must be in order to achieve the desired degree of accuracy. "Any index, though specific to whatever group of assets it represents is not specific to any single one of the assets in the group, whose relative price changes are dispersed around the index."[34] Previous research indicates "very little statistical accuracy is gained by the use of the most specific indexes currently available at very little cost."[35] Thirdly, the criticism has been voiced that any given price index can measure only overall changes in ratios of exchange as there is no available methodology for segregating price changes caused by changes in resource quality from price changes caused by changes in productive efficiency in producing resources from price changes caused by a myriad of other things which affect either long-run or short-run supply and demand.

Objections to the use of these methods of estimating a replacement or reproduction cost again illustrate the importance of the objectivity concept; but the importance of accurate information is also pointed out. Accordingly, it is necessary to establish another tentative general hypothesis in order to properly evaluate an energy systems approach for estimating replacement cost. This hypothesis may be stated as follows: *the general energy systems approach provides accurate estimates of the current reproduction (or replacement) cost of a specified long-lived productive resource.*

Conclusions

The purpose of this chapter is to convey to the reader a description of the historical evolution of the accounting problem* under consideration, the previously proposed solutions, and the objections to those solutions. It is believed that a comprehensive study of the problematic situation, even though in very summarized form, allows the inquirer to gain further insight concerning the various interactions inherent in the economic, political, and legal environment which exert pressures on the component issues of the problem.

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*The measurement of long-lived resources. This problem includes the selection of the appropriate measurement base to be used as the valuation coefficient.

Second, the background information developed is used to provide the logical justification for some of the more important assumptions necessary to the inquiry. Also, the logical reasoning involved in choosing the general working hypotheses proposed in order to evaluate the general energy system approach to measuring current acquisition exchange ratios is described.

Finally, it has been stated that this inquiry is constrained to the development and evaluation of a measurement system. In this chapter, it is noted that development of a logically consistent, empirically verifiable, and objective measurement system is not expected to completely resolve the accounting problem because of the "relevance to user needs" issue. However, having such a measurement system will narrow the scope of the controversy and thus aid in final resolution of the problem.

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CHAPTER III
GENERAL ENERGY SYSTEMS THEORY--A BASIC DESCRIPTION

In this chapter general energy systems theory will be discussed including an examination of the relationship between energy and economics. However, before this discussion begins, it is necessary to provide clear definitions of the terms energy, power, and work. In physics, energy refers to the capacity to do work,* work is done when a body is moved by force; and power is defined as energy per unit of time, such as energy per second.[1]

These definitions can be clarified by considering some concepts commonly used in physics.

> The absolute unit of work in the Centimetre-Gramme-Second system is one erg. It is a very small unit, being the work done when a body of 1.02 milligrammes weight is lifted vertically by one centimetre against the gravitational force at sea level. Ten million ergs are called a joule and a joule per second is a power unit called a watt. A kilowatt (1000 watts) is the practical unit of power. However, horsepower is another power unit defined as work of 550 foot-pounds per second or .745476 kilowatts. Since power is energy divided by time, the product of power and time is energy. A practical unit for energy is the kilowatt hour; that is, the work done by a one kilowatt engine in one hour. It will lift a load of one metric ton over a difference in level of 1119 feet.[2]

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*Or the capacity to alter relationships between man and his environment.

Potential energy may be thought of as "stored work;" in other words, it describes the capacity to perform work or the energy available to carry out processes and account for phenomena. The classic illustration of potential energy is restated by Hans Thirring using a mechanical energy example which defines potential energy in terms of a

> heavy body on a higher level which can do work by descending to a lower level and hoisting (by means of a rope and pulley) a load from a lower level. In this situation potential energy is defined as the product of its weight and the height above a certain zero level. Potential energy must be related to a certain zero level because a body cannot do work by losing its potential energy unless it is allowed to descend to a lower level.[3]

Mechanical energy may be calculated in terms of motion, force, and distance. Thirring states that one way to define mechanical energy is

> to set up an aribtrary unit to measure force (such as pounds) and another to measure distance (such as the foot); the composite figure when both are multiplied together is energy in terms of a measure of weight (foot-pounds). However, to measure force in motion requires a new dimension--acceleration, the rate of change of speed of movement. The specific relationship between rate of motion and the energy required to produce it has been established empirically as: energy equals one-half the mass times the velocity squared ($e=\frac{1}{2}mv^2$). Therefore, if mass remains unchanged, to increase the rate of motion of an object requires energy in proportion to the square of the velocity. Moreover, if there is an object moving at a given velocity, the above expression provides a mathematical expression of its ability to do work.[4]

In physics it is noted that when an object falls from a higher level to the ground, its original potential energy (while stationary at the higher level) is converted into kinetic energy (potential energy in the form of a moving object) during the fall and afterwards, partly converted into mechanical work by making a hole in the ground and partly dissipated into the invisible motion of its single molecules and atoms. The kinetic energy of the invisible molecular motion of a body is nothing else but its heat content. In other words, heat is the energy of the disordered and invisible motion of the atoms and molecules of a body. Therefore, both heat and mechanical work are forms of energy. Because each is a form of energy it is possible to convert heat to mechanical work and mechanical work to heat. Likewise, there are conversion factors for converting the measuring units for mechanical work to the measuring units for heat. For instance, a kilowatt hour is a measure of mechanical work; a BTU (British Thermal Unit) is a measure of heat; and one kilowatt hour equals 3412.75 BTU's.*
Energy, then, can be measured in terms of either heat units or mechanical work units.

Thermodynamics--The Science of Energy

Since energy can be converted from one form to another and since it is desirable for man to accomplish

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*See Table 1 for other conversion factors.

TABLE 1. CONVERSION FACTORS FOR ENERGY MEASURING UNITS

Gram-calorie (gcal) - amount of heat necessary to raise 1 gram of water one degree centigrade at fifteen degrees centigrade.

Kilogram-calorie (kcal) - 1,000 gram-calories.

British Thermal Unit (B.T.U.) = amount of heat necessary to raise one pound of water one degree fahrenheit = 252 gcal = .252 kcal.

Joule = .24 gcal = .74 foot-pounds.

Watt = one Joule per second = 14.3 gcal per minute = 3-7 x 10^{-7} horsepower hours.

Kilowatt = 1,000 watts

Kilowatt hour (kwh) = 3412.75 B.T.U.'s = 860.013 kcal = 1.34 horsepower hours.

Horsepower = 550 foot-pound per second = 10.688 kcal per minute = .745476 kilowatts.

Horsepower Hour = 2544.48 B.T.U.'s = 641.56 kcal.

Source: U.S. Bureau of Mines

this conversion, a scientific body of knowledge, usually referred to as thermodynamics (from the Greek roots therme meaning heat and dynamis meaning power), has evolved in this area. Thermodynamics is a branch of physics which defines and interprets the relationships between energy, heat and work.

British scientist James P. Joule established a mathematical measure of the exact relationship between heat and work, which led to the establishment of a principle called the First Law of Thermodynamics (or the Law of Conservatism of Energy).[5] Basically, this principle states that energy may be transformed from one form into another, but it is never created or destroyed. Sunlight, for instance, is a form of energy which can be transformed into work, heat, or the potential energy of food (energy stored as matter), depending on the situation but none is destroyed. This means that energy, which by natural and artificial processes is permanently converted from one form into another, is never lost or generated from nothing.

This law encouraged Joule to attempt to devise a system for generating a large amount of work by exploiting very small changes in temperature. However, these efforts were not successful and resulted in stating of the Second Law of Thermodynamics by one of his students. The Second Law may be stated in several ways as follows: No process involving an energy transformation will occur unless some of the potential energy is degraded from a concentrated form into a dispersed form; or, because some energy is always dispersed into unusable heat energy no transformation of energy (i.e. the transformation of heat into mechanical work, or vice versa) is 100 percent efficient. In other words, even though the First Law of Thermodynamics states that energy can neither be destroyed nor created, another process results in available energy continuously changing to a lower, less usable form.* It is this process which is referred to as the Second Law of Thermodynamics (or as some prefer, the entropy** law). This law is used to describe the processes of energy conversion in many systems, including those of physics, biology, and ecology. For instance, a heat engine is a process which converts some of the original energy content of fuel (see Table 2 for the energy content of various fuels) to mechanical work through operation of the engine and dissipates the rest as waste heat (it is waste because it has lost the potential for driving a process). A second example which can be described would occur in ecosystems where low entropy is achieved by a continual dissipation of energy of high utility (for example sunlight which is capable of driving the photosynthesis process or plant glucose which drives the respiration process) to energy of low utility (low utility in the sense that it has no potential for driving phenomenon).

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*The first law is not violated as energy is neither created nor destroyed; however, potential energy is degraded from a form capable of driving phenomena into a form that is not capable of doing so; although, even as random heat, technically, energy still exists as molecular motion.

**Entropy (from a Greek word meaning transformation) is a term used to describe the relationship of energy to a process. Furthermore, the terms "high entropy" and "low entropy are used to designate available energy for use in a given system (whether a power plant, automobile engine, or an ecological system). Available energy is always low entropy, and can be used for something. For example, a pound of coal can be burned to produce electricity; therefore, the coal is low entropy. High entropy is energy which is unavailable for use; for example, the heat rejected from the power plant cannot be collected and used to produce more electricity. In other words, low entropy has a high degree of order and high entropy has great disorder with respect to the system in question. For this reason, low entropy refers to high quality energy and high entropy to low quality energy.

Another way of understanding the entropy law is to visualize the entropy process in terms of the degree of disorder. Thus, different forms of energy can be arranged in an order, the highest form of which is the one with the least disorder or entropy. Moreover, energy with the lowest entropy has the greatest potential to perform work and may be degraded into a lower form (to high entropy entropy), but can never be wholly converted back into a higher form. It is possible to transform energy from a less useful to a more useful form, but only at the expense of degrading a fraction of the initial amount of potential energy present. Therefore, "the real message of the entropy law is that energy, unlike most resources, cannot be recycled. The total potential, or capacity to do work, in a given amount of

TABLE 2. THE ENERGY CONTENT OF VARIOUS FUELS (IN MILLIONS OF BTU'S)

Bituminous Coal	26.20 per short ton
Pennsylvania Anthracite Coal	25.40 per short ton
Kerosene	5.67 per barrel (42 gal.)
Gasoline (motor fuel)	5.22 per barrel
Gasoline (aviation)	5.05 per barrel
Fuel Oil (Grades 1-4)	5.83 per barrel
Fuel Oil (Grades 5-6)	6.29 per barrel
Crude Oil	5.80 per barrel
Petroleum Coke	30.12 per short ton
Coal Coke	24.80 per short ton
Coke Breeze	21.00 per short ton
Wood	20.96 per cord
Natural Gas Liquids	4.01 per barrel
Wellhead Natural Gas	1.08 per cubic foot
Natural Gas (dry)	1.03 per cubic foot

Source: U.S. Bureau of Mines

energy can be used only once; and, having been used, cannot be recaptured in its entirety."[6]

Energy and Man in Historical Perspective

Man, like all living organisms is a consumer of energy (or is an energy convertor), because animal life depends on metabolism fuelled by food, which supplies to the body the necessary amount of energy. Thirring describes the energetics of the human body as follows:

> The total energy resulting from 'burning' the food-fuel in the process of metabolism is used for different purposes, among which there are three which play a dominant role:
>
> 1) Chemical energy used for building up and regenerating the living tissues of the body.
>
> 2) Energy needed for doing muscular and mental work.
>
> 3) Heat for compensating the losses by conduction, radiation, and evaporation.[7]

Beyond the biological minimum the amount of energy required by man is set by the goals he seeks. Because few, if any, societies exist where men voluntarily choose to exert no more energy than that which is required for survival, manipulation of energy has been an essential component of man's society. "Although primitive people and most animals can alter their behavior to adapt to changing environmental restriction, the reverse ability to substantially alter the environment is uniquely man's."[8] From their earliest earth origins, human beings have continually sought "to minimize their labor by the use of tools. During the late Paleolithic period--some 12,000 to 20,000 years ago--cave dwellers in southern Europe painted images of what may well have been the first machine, or sophisticated tool used by man. On the cave walls are pictured traps used for capturing mammoth and bison."[9] By using this trap, early hunters were able to increase the probability of their existence. They stretched their available biological energy, in the form of food, by utilizing tools to construct the trap and provide themselves more energy in the form of flesh of the bison and mammoth. Muscular work, done by laborers, housewives, slaves, and domestic animals, contributed the greatest proportion of mechanical work among civilized nations in former times, and still does among primitive peoples today. "Man power and animal power is physiological energy and is denoted by the term 'animate energy' which means the potential energy is maintained by food and fodder."[10]

On the other hand, "purely physical energy is maintained by using fuel, wind, water-power, and other such sources, and it is designated as inanimate energy."[11] These different sources of inanimate energy can replace one another, but inanimate energy sources can be exchanged for food resources only indirectly by subsidizing production of fertilizers, farm equipment, transportation equipment, and so on. The prehistoric domestication of animals represented a multiplication in the power resources available to man but not by very significant amounts. During this time, the power available limited man's ability to irrigate, cultivate, and survive. It has been the application of inanimate energy which caused the decisive steps in the evolution of man's society.* The most vital discovery of the Stone Age was how to make fire by rubbing together two pieces of wood. This revolutionary discovery has many repercussions in the history of energy. For early man fire meant light, heat, protection, and a number of other things.

The most significant of these other things is that "the application of fire and its heat led to the transition from the Stone Age to the Bronze Age and then to the Iron Age by making possible the production of higher quality tools."[12] So energy facilitated the creation of capital goods in the form of tools from nature's raw materials, and the tools thus created were of a higher quality than the earlier tools made by using the raw materials in substantially natural form. In addition, energy in the form of heat for warmth increased the size of the world's habitable area. However, Thirring states that man eventually discovered that energy could be used for purposes other than for warmth.

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*Leslie A. White of the University of Michigan suggested that cultural evolution can be measured in terms of the increasing amount of energy harnessed per capita per annum. In other words, the development of energy sources that are independent of immediate biological processes has been the factor of greatest importance and this is a yardstick that seems generally to agree with human experience: Industrialized societies harness many times more energy per capita per annum than nonindustrialized ones and in areas where the two have competed the nonindustrialized societies have inevitably been displaced, absorbed, or destroyed.

> For thousands of years, through all the prehistoric ages, heat was the only form of inanimate energy used by man. As noted earlier, to do the work necessary to supply food, clothing, and shelter man had to use his own muscles or those of his slaves or animals. It was only in historic ages, many millennia after the invention of fire, that a small part of human and animal labor began to be replaced by machines using the natural forces of water and wind.[13]

The Chinese were probably the first to use windmills. Waterwheels, originally devised by the Babylonians for irrigation, were used in the Roman Empire for driving mills such as saw-mills and hammer-mills. The early application of water power is described by Chauncy Starr as follows:

> The horizontal water-wheel used by the Romans, which operated by exploiting natural differences in elevation, operated with a power capacity of perhaps .3 kilowatt. By the fourth century the vertical waterwheel had been developed to provide about two kilowatts of power. These wheels were primarily used for grinding cereals and similar mechanical tasks. By the sixteenth century the waterwheel was by far the most important prime mover, providing the foundation for the industrialization of western Europe. By the seventeenth century its power output was reaching very significant levels. The

> famous Versailles waterworks at Marly-la-Machine is believed to have had power of 56 kilowatts.[14]

The windmill first appeared in western Europe in the twelfth century. It was variously used for grinding grain, for hoisting materials from mines and for pumping water. The windmill had a respectable capacity ranging from several kilowatts to as much as 12 kilowatts. Starr then describes the evolution of using fossil fuel energy to supply mechanical power as follows:

> The development of the steam prime mover is relatively modern compared with the windmill and the waterwheel. As early as one A.D. Hero of Alexandria demonstrated the famous Sphere of Aeolus, a steam reaction turbine on a toy scale. Not until the seventeenth century was steam used effectively. At this time Thomas Savery invented a steam pump which was a pistonless device using the vacuum of condensing steam to pump water. Early in the eighteenth century engines using a moving piston were developed as power sources of several kilowatts. The steam engine was the first mechanical prime mover to provide basic mobility. It was some time, however, before this mobility was used. The early Industrial Revolution was based on the waterwheel and the windmill as prime movers. Thus, the location of industrial centers, factories, and cities was primarily determined by the availability of those power sources. It was the geographic limitation on the expansion of water power that gave the steam engine an opportunity to continue the growth of manufacturing centers. The first use of the steam engine was an auxiliary to the waterwheel: to pump water to an elevation sufficient to increase the wheel's power. It was not until the middle of the nineteenth century that the steam engine became a principal prime mover for the manufacturing industry of the western world. The contribution of large

> power machines to the social development became important after 1700. Since 1900 a steadily growing variety of smaller power-conversion devices have been introduced whose chief virtue is mobility. From 1700 on, the power output of energy conversion devices has increased about 10,000 times. Most of this growth has occurred in the last 100 years so it has had its major impact only recently. It is this technological capacity that makes recent decades reflect accelerated energy utilization.[15]

The growth of energy use has been so rapid in the recent past because utilization of energy depends on two factors: available resources and the technological skill to convert energy resources to useful heat and work. Energy resources have always been obtainable from the environment; however, power devices capable of converting the energy into useful work have been a recent historical development. The development of these prime movers (energy converters) required and supported the technology of iron and steel fabrication and it involved the rise of the railroads.

In summary, it has been shown that the use of energy has been a key to the supply of food, to physical comfort, and to improving the quality of life beyond the rudimentary activities necessary for survival. Furthermore, man uses energy converters other than his own body to achieve his ends and the energy these converters make available to him is measurable. Moreover, the relative advantage of using converters over using man's own physical effort may be calculated.

The growth of the world's population and the manifestations of greater per capita affluence all appear to show significant increases in parallel with the growth in energy use. In other words, as put by Ray Rappaport,

> the increasing size and complexity of human organization is related to man's increasing ability to harness energy. The relationship is not a simple one; rather, it is one of mutual causation. For example, increases in the available energy allow increases in the size and differentiation of human societies. Increased numbers and increasingly complex organizations require still more energy to sustain them and at the same time facilitate the development of new techniques for capturing more energy and so on. Simultaneously with this growth rapid developments in learning, in the arts, and in technologies of all kinds can generally be observed.[16]

Although one must be cautious when dealing with pluralistic and interacting relations, a strong case can be made for the proposition that the productive utilization of energy has played a primary role in shaping the science and culture of the past 350 years. This proposition finds some support in the relation that it is possible to observe today between the per capita consumption of energy for heat, light, and work and the per capita gross national product of various nations.

Table 3 provides a rough idea as to how, in the evolution of human civilization, new sources and new applications of inanimate energy were added to existing sources for providing industrial and transportation power as well as domestic and industry heat.

Table 3. Sources of Inanimate Energy as They First Appeared at Different Stages of Civilization

Stage of Human Development	Domestic Heat	Industrial Heat	Industrial Power	Transportation Power
Animal Stage	--	--	--	--
Primitive Cave Man	wood fire	--	--	--
Prehistoric Civilization	wood fire	wood fire	--	--
Antiquity	wood fire	wood fire	wind water	wind
Since about 1250	wood fire	coal	wind water	wind
Since about 1400	coal	coal	wind water	wind
Since about 1710	coal	coal	steam	wind
Since about 1820	coal	coal	steam	steam
Since about 1890	coal	coal	electricity	electricity
Since about 1900	oil products	electricity	electricity	petroleum motors
Since about 1955	oil products	electricity	atomic power	atomic power

Source: Hans Thirring Energy for Man: Windmills to Nuclear Power (Bloomington, Indiana: Indiana University Press, 1958), p. 32.

Energy Systems Theory and Economics

For purposes of this paper, economics will be restricted to the study of that "subsystem of the total social system which deals primarily with exchange, the institutions of exchange, and with the goods or services which are exchanged."[17]* Exchange will take the form of mutually agreeable roles where one person says to another, "you do something I want and I'll do something you want." Within this context, "economics becomes concerned with the allocation of the scarce means and resources available to satisfy the varied and unending wants of the social system."[18]

Where exchange opportunities are continually available, it pays for people to specialize in the production of one commodity which can be exchanged for other commodities similarly produced by specialized producers. For instance, the U.S. economy is a vast network of exchanges or trade where individuals are dependent upon each other. An individual does not as a general rule produce for himself any significant portion of the goods and services that he wants and needs. Indeed, he lacks the technical skill required to produce a host of the manufactured goods that are an integral part of his standard of living. Any attempt by one individual to produce such a variety of things for himself would be very inefficient and wasteful, if not impossible. Accordingly, the bulk of the goods and services utilized by Americans are purchased from a large number of private business firms. These organizations specialize in various phases of the highly complex task of transforming the resources of labor, capital, and natural raw materials into commodities and services.

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*The total social system consists of all the people in the world, all the roles they occupy, all their patterns of behavior, and all their interactions with the other systems and subsystems of the world which form a total system of the planet earth.

In this type of market economy, an economic concept which may be called the "terms-of-trade" becomes important because every human being or organization within the social system has inputs from and outputs to the rest of the social system.[19] The "terms-of-trade" refers to the ratio of physical inputs received to the physical outputs provided in exchange and is an important concept in understanding economic behavior. Typically, favorable "terms-of-trade" means a lot of input is received relative to the number of units of output given up. However, when the inputs and outputs are heterogeneous aggregates of all sorts of things, the problem of measuring and communicating the results of exchange activity (in other words, the problem of measuring one relative to another), of necessity, involves valuation.[20]

Money is the most common measure of value; thus, for the existence of a market system it is necessary that economic activity be organized in terms of making and spending money. In other words, in any exchange, "terms-of-trade" may be measured by the ratio of what one party gives relative to what he receives and if money is one of the things exchanged, the ratio of exchange becomes what is referred to, in economic terminology, as a price. Moreover, receiving more input for the same dollar output means a lower price per unit of input purchased, and, thus, an improvement in the "terms-of-trade."

In the market economic system, the survival of an organization, such as the firm, depends on its capacity to produce outputs of a total value at least equal to the acquisition cost of its inputs. For instance, there is the theory that in a perfectly competitive market the price of each product in an equilibrium will be equal to the average total cost of the marginal firm. The average price is the total revenue (money inflow) divided by the physical quantity of the output commodity or commodities, and the average total cost is the total dollar value of all the inputs divided by the physical quantity of the output commodity. The theory can also be stated as follows: in an equilibrium of the price system the total money revenue of the marginal firm must be equal to its total cost, including rent and normal renumeration of capital.

In energy systems theory, the whole economic process is regarded as one by which "the world is organized into structures of increasing improbability with the accompanying degradation of potential (low entropy) energy to high entropy energy as required by the Second Law of Thermodynamics."[21]* Therefore, the process of production consists of transforming inputs of higher probability (i.e. high entropy) items (such as soils, ores, and raw materials of all kinds) into outputs of much less probable things (such as automobiles, buildings, and so on) by utilizing available energy (i.e. performing work).[22] However, consumption processes then continually wear down these improbable structures into more probable items, such as dust, soil, chemical minerals, heat, and so on.[23]

With respect to any system (social, natural, biological, economic, and so on), three broad kinds of inputs and outputs can be identified:

1. Information for organizing, operating and maintaining all the components and functions of the system itself;

2. Matter in the form of either organized or random structures; and

3. Potential energy or work.

When energy is either an input or an output of a particular system, one or some combination of three types of work will occur:

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*Recall entropy is the term used in thermodynamics to designate the magnitude of disorder. High entropy refers to a high level of disorder and low entropy to a high degree of order.

a. Storing work which involves the force of one potential energy source directed against the back force from another potential energy storage. It can be shown that the power flow when storing energy at an optimum rate requires a 50 percent drain. Therefore, the energy cost of the process can be measured either by the energy stored or by the total power flow, which is twice the storage rate when the process operates in optimal fashion.[24]

b. Processing work in which power flows from the

> energy source and passes through the system, arranging matter but effecting no storage and no final acceleration. All the energy eventually degrades into the heat drain, but first useful ends are accomplished. Thus, work done against frictional forces to accomplish rearrangement without storage leads to 100 percent drain; however, arrangement of structure is a necessary principal task in preserving or establishing any kind of order, whether it involves the maintenance of a living being or the operation of an industry. The energy cost of the process is not measured in terms of the energy stored, for none is stored; but it may be measured by the power delivered to accomplish the work.[25]

c. A third kind of work involves the flow of potential energy from its storage into the acceleration of objects. That is, energy is passed from storage into the kinetic energy of the object. But this class of energy flow is only a relative energy transfer and not a true energy transformation as were the prior two. This is because the work done in acceleration requires no heat-sink dispersal and the energy stored in kinetic form is still available to drive other kinds of work. Thus, energy flows involving accelerations and work against inertial forces are not energetic transformations in the same sense that those requiring loss of potential energy are.[26]

Although all inputs and outputs can be arranged in one of the above three classifications, it is important to note that each of the three may take a large number of different forms. Also, output of more organized and improbable structures can occur only if at least one of the three types of work is performed by a system. The Second Law of Thermodynamics states that this requires potential energy to be degraded from low entropy to high entropy energy. Moreover, it is possible to determine the heat value of the energy degraded in accomplishing the necessary work to transform inputs into a desired output.

For economic exchange almost any commodity can be used as money, provided it is generally acceptable to sellers in exchange. It is the function of money that is important. As the medium of exchange, it serves as generalized purchasing power. Instead of being forced to seek out that particular person who has just exactly what is desired and who is willing to barter it for exactly the commodity owned, individuals can trade with money which greatly simplifies the system of exchange. In other words, when people earn money by supplying labor and other services, they are exchanging these resources for the ability to obtain a portion of the current output of goods and services.

The market economic system may be broadly illustrated in Figure 1. It is seen that business firms purchase natural resources (previously discussed as the input termed matter), and hire services (potential energy input) from the owners of these inputs. The money payments made for these in the form of wages, interest, rents, and so on become the disposable income of the labor system.* In turn, the individuals and families that comprise the labor system spend their disposable income for the goods** and services produced by businesses, thereby creating the demands which businesses try to satisfy in their attempt to earn money profits. As Figure 1 illustrates, there is a continuous flow of money payments from consumers in the labor system to business firms and back to the labor system, the latter matches a flow in the opposite direction of productive services and finished goods and services. It is the opposite

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*Here the labor system refers to all of the individual people living in a specified social system.

**An economic good (either an energy processor, termed capital equipment and consumer durables in economics, or a nondurable consumable) may be defined in energy systems terminology as a high probability natural resource which has been changed--by degrading low entropy potential energy in the performance of work--into a low probability, highly organized form of the type desired by man for use in his living process or social system.

FIGURE 1 - LEGEND

1. Natural resources (money payments go to labor system since raw materials are owned by people).
2. Productive services and natural resources utilized.
3. Productive services.
4. Payments for productive services and natural resources by users of these items.
5. Income of individuals who provide useful services.
6. Money payments for the finished goods provided by business firms.
7. Finished goods used and consumed by people.
8. Output of finished goods for people.
9. Money payments made by people to obtain finished goods.
10. The flow of used (degraded) energy and matter back to the natural system. The matter is recycled by natural processes and the degraded energy (i.e. heat) radiates from the earth.

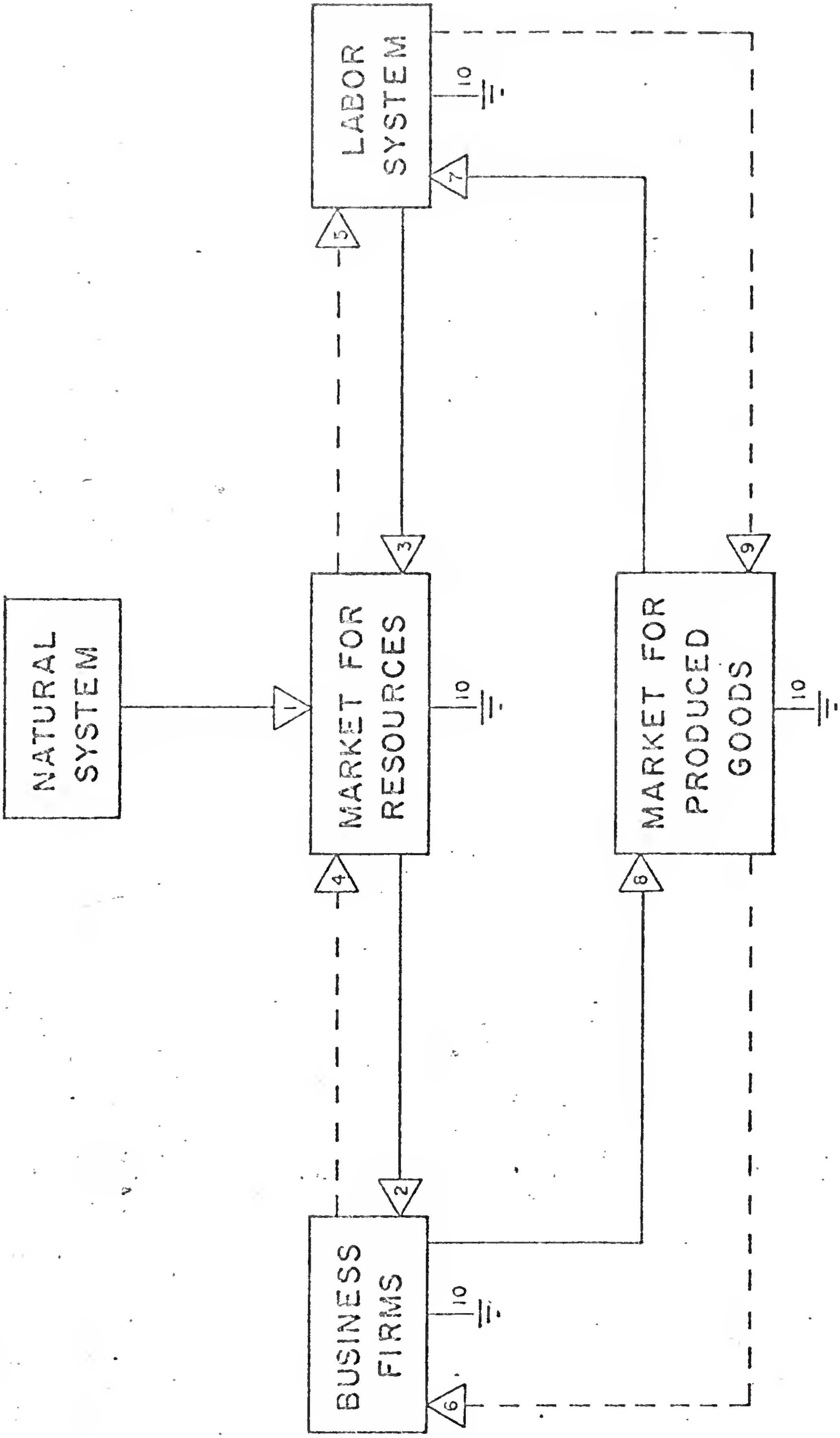

FIGURE 1. ILLUSTRATION OF A MARKET ECONOMY

flows of money and goods and services that compromise the myriad exchanges that are the most readily observed feature of the economic system. The heat sinks (Number 10) illustrate that the consumed goods flow back to the natural system as waste where natural processes convert them back to their disordered form using the sun's renewable energy. The degraded energy is radiated from the earth into space.

Figure 2 depicts man's economic system in greater detail utilizing energy systems methodology but without being concerned with the very complex subsystem interactions. Here solar energy results in plant structure being produced in the natural system by photosynthesis and respiration. Plants then provide a source of energy for both man and animals, but man may tap this natural energy source in the form of food either by consuming plants directly or by consuming other animals.

In analyzing natural systems, it is discovered that minerals recycling is an example of what is called a feedback loop in energy systems terminology, and it is "the natural process through which consumers of the outputs of a system reward that system by feeding back the inputs necessary to the production of more output."[27]
These feedback loops provide an information service for connecting producer systems to consuming systems. As stated by Odum, .

FIGURE 2 - LEGEND

1. Natural energy (from sunlight) utilized directly by man (process waste, recreation, etc.).
2. Natural energy utilized by the natural system.
3. Man's waste.
4. Gross energy obtained by man from the natural products he uses.
5. Animate potential energy transformed through the natural system into inanimate fossil fuel potential energy.
6. Dollar payments for productive goods and services (energy from processing or storing work) and for inanimate energy (stored energy).
7. Goods and services used to obtain the inanimate energy.
8. Gross inanimate energy consumed by man.
9. Dollar payments for inanimate energy.
10. Dollar payments for productive goods and services (energy) and for natural products (energy).
11. Goods and services (energy) needed to obtain natural products.
12. Gross energy equivalent of the natural products used by man.
13. Dollar payments for natural products.
14. Gross inanimate energy from the natural systems.
15. The flow of degraded energy and matter back to the natural system. The matter is recycled and the degraded energy radiates from the earth.

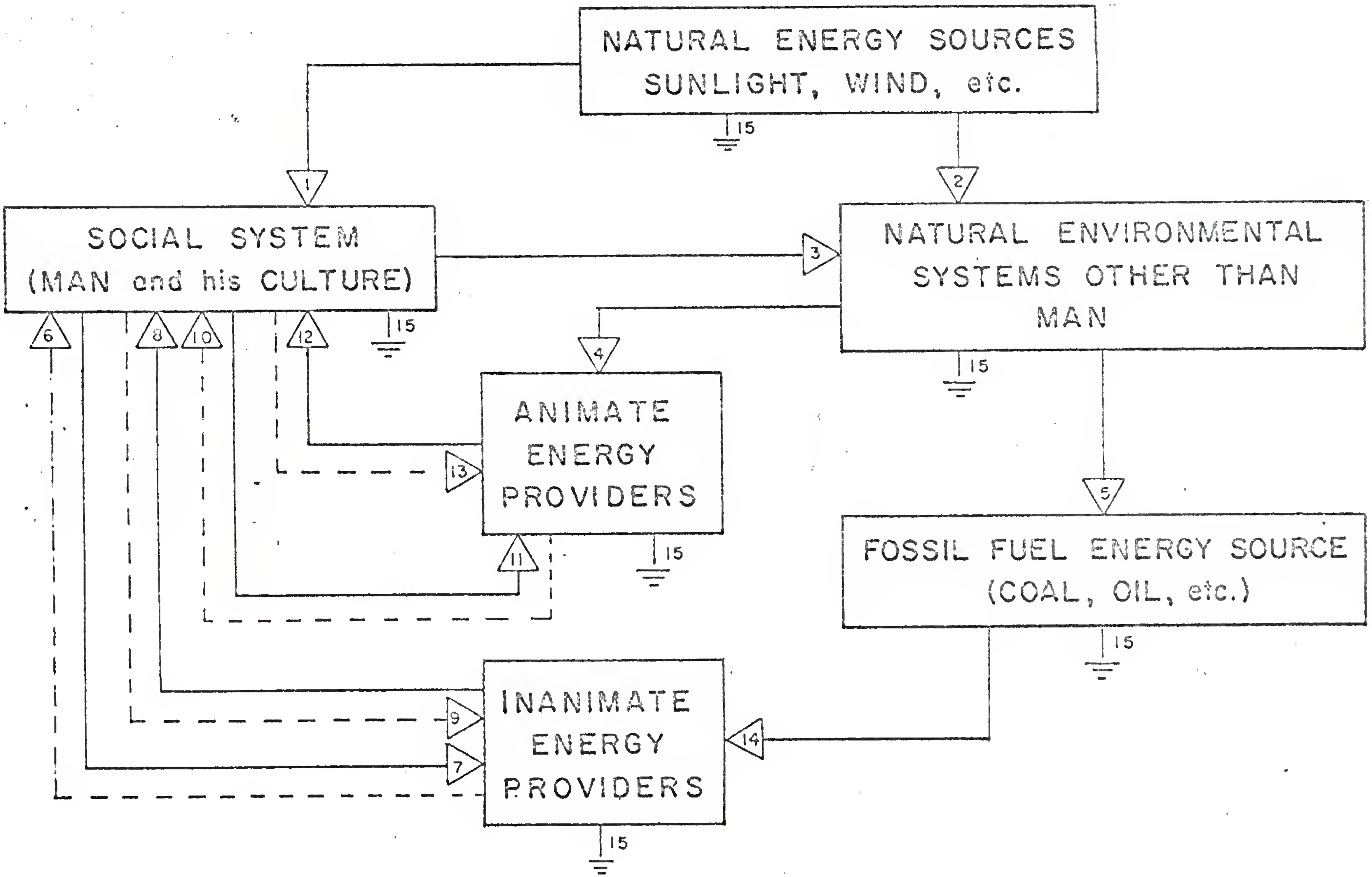

FIGURE 2
ENERGY FLOW DIAGRAM OF AN ECONOMIC SYSTEM

> this information, feedback loop process has developed in nature and is the natural selector because the absence of this reinforcing loop would eventually result in the extinction of the system of particular "consumers." This would occur as soon as the "producers" delivered all the nutrients available to them to the consumers as food. Without additional nutrients production ceases and the consumers starve. The stronger this feedback loop the more necessary the consumers are to the producer's survival; thus, there is a higher probability of both surviving.[28]

In the exchange system, money serves the same information function as minerals do to the plant system by way of a feedback loop in which consumers feed back currency in exchange for the economic goods and services.* It is this feedback loop of currency to business firms which motivates business firms, and indirectly decides what commodities will be produced and in what quantities, how the commodities will be produced, and for whom the commodities will be produced.[29] Moreover, the assertion that the money flow system is the control mechanism for directing economic activity in the U.S. social system is supported by the economic dislocation which was observed when the money flow system was disrupted because of the near collapse of the banking system during the 1930's.

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*Highly organized, low probability forms of high probability resources formed by work being performed with the associated expenditure of energy as required by the Second Law of Thermodynamics.

In addition, further observation of the activities which occur in natural systems indicate that metabolism in a biological organism is parallel to production in an economy. Metabolism consists essentially of the transformation of inputs into outputs in accordance with a functional relationship between them with an associated degrading of potential energy as work is done. Thus, any biological organism has inputs, such as food, gases from the atmosphere, water, minerals from the soil, and so on; it also has outputs of matter, gases, wastes, and ultimately its dead body (i.e. a structure of tissue built through biological processing of the inputs*). In other words, each subsystem, natural or manmade, is a "node" in a network of inputs and outputs and "the network must ultimately be circular (through feedback loops) or subsystems will cease to exist."[30]

Man must perform work in order to obtain the outputs of the natural system in the form and place he desires. Therefore, the actual net energy available to man is equal to the gross potential energy of the natural outputs minus the energy degraded in the task of obtaining the natural outputs in the form, condition, and location desired by man.

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*Analagous to the capital equipment sector of an economic system as its function is to process inputs into outputs which function then to process more inputs into outputs. The biological organism devotes part of its processing of inputs to maintenance and expansion of its own system which then is available to process additional inputs in the future and this expansion will continue until at least one of the inputs becomes a limiting factor.

The natural system may be rewarded by receiving matter, either in the form of man's waste or in the form of various organic fertilizers and chemicals. It may also be rewarded by man aiding in the natural processes. For instance, the soil may be tilled to facilitate nature's production of the plant structure or animals may be domesticated and cared for in order to provide man with the food he needs for his processes. However, some of these rewards require that potential energy be degraded and this reduces the net potential energy which is obtained from the natural system. In fact, it appears that unless these rewards result in a greater increase in the potential energy to be obtained from the natural system than the energy expended in providing these rewards, the social system is better off not providing the reward. The owners of the natural system's outputs also receive a reward in the form of a monetary payment for the natural outputs utilized (e.g. wood and food products such as grains, fish, shrimp, and so on may be typical products from the natural system).

In addition to natural systems which tap the daily energy from the sun, Figure 2 depicts the addition of stored solar energy in the form of fossil fuel to the system. Man must perform work, with a commensurate expenditure of energy, in obtaining and processing fossil fuels. But the energy he controls with the processed fossil fuels is far greater in magnitude than the energy he expended as work in obtaining the fossil fuel. Thus, the stored fossil fuels provide a net energy yield to man. Man then uses this net energy to multiply his own ability to perform work. It is this ability to work* that enables man to "feedback" to the environment and manipulate natural systems in achieving his desired goals. Thus, man utilizes the fossil fuel energy to provide the power which enables him to fashion energy converters (capital equipment), buildings, and other economic goods from nature's raw materials. Some of these goods are then applied in the natural environment to either extract more raw materials or to aid natural systems in carrying out a function useful to man (such as using fertilizers and pesticides to increase the concentration of nutrients in the soil thus facilitating the photosynthesis--respiration process of food producing plants). However, it should be pointed out that energy is also needed in many cases to process man's waste in order that natural systems will not be harmed (negatively rewarded) by this feedback of waste. There is some debate, at present, devoted to the question of whether man might not be better off energetically by developing natural systems (which use the energy of the sun) for this function of reprocessing waste than he is by utilizing his limited fossil fuel resources in accomplishing this objective. A critical problem here being the corollary question as to whether the natural system can perform this reprocessing function without any subsidy from man given the chemically complex waste which modern man generates.

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*Work is done when weights are lifted, when objects are arranged, or when anything useful happens; in other words, when energy from a potential energy source is flowing through and driving a useful process, it is described as the rate of doing work. See Pages 87-88 for types of work.

Conclusions

Very few of the economic goods utilized or consumed by man are found in their raw state in nature. Rather, they are the result of the conversion of some raw material found in nature. This conversion may consist merely of a change in time or place but it must be made in order to create utility for the vast majority of the economic goods enjoyed by man. Moreover, work must be performed to accomplish this conversion and it is possible to physically measure the energy equivalent of the work needed to produce any particular economic good. As summarized by Odum,

> it has been shown that in the affairs of forests, seas, cities, and human beings, the potential energy sources that are available flow through each process, doing and driving useful work for that process. The work may consist of storing work, processing work, or acceleration. Therefore, the availability of power sources determines

> the amount of work activity that can exist, and control of these power flows determines the manipulation possible in man's affairs and his relative influence on nature. That any and every process and activity on earth is an energy manifestation measurable in energy units is a fact of existence. One may say that pehnomena on earth are energetically determined.[31]

The energy systems approach can be used to effectively describe both natural systems and man's economic activities. This conclusion is reached because it is possible to state all inputs and outputs in terms of energy--either the stored potential energy inherent in the matter itself or the potential energy degraded in performing the work necessary to rearrange high probability, disordered matter into low probability, ordered matter. Therefore, it is possible to relate all of these systems as they are all governed by the laws of thermodynamics. Odum reaches the same conclusion as follows:

> Flows and storages of energy and matter can be mapped and quantified, remembering that many materials contain potential energy. For instance, the discharge of organic waste into a river is actually a discharge of matter and potential energy. Eventually, through the action of microbial heterotrophs, the chemical potential is released in the form of biological energy, and the matter is degraded to its elemental nutrient form. It is not usual to think of matter or nutrients as energy but they are as necessary to chemical reactions as fossil fuels or human labor and any input to a process has its energy contribution to that reaction. Furthermore, there are formulae for calculating the energy equivalent value of that contribution.[32]

In ecological systems it was shown that there is a positive feedback loop through which a consumer of potential energy rewards its source by passing necessary materials back to it.[33] Thus, with the nutrients circulating as currency, compatible combinations of plant and animals are self-rewarding. In other words, such feedback loops and the intertwining of loop circuits provides the system a method for selecting only those species and circuits that contribute to the whole cycling, because species whose work efforts are not reinforced are eliminated as soon as they utilize all the raw materials or energy available to them. Moreover, in the social system, man himself serves at the system control level, as a selector of the various possible combinations in which the system components may be arranged. In the U.S. this selection process is made operational via a free market economy where, in the absence of market distortions, the prices for items in abundant supply tend to fall and the prices for items in short supply tend to rise. A decrease in price encourages producers to cut back production, thus diverting resource inputs to other uses. Conversely, a rise in price provides the economic incentive to expand production of the needed components. Thus, in man's complex system he has arranged a feedback currency that is as informative as the geochemical recycling of natural ecosystems. He invented money, which is fed back in reward for work done. The "flow of each population is thus looped to at least one other population, and by interconnecting loops the economic system provides rewards for each and a means by which the system components are designed."[34]

Money flows keep a system's members contributing useful work for the network and provides a means of organizing energy flows. Therefore, money may be considered a form of potential energy (arising out of its ability to control or command and call forth work) and the dollar flow is the amount of currency the consumer must supply the producer unit in order for the particular energy flow (opposite to the dollar flow) to be supplied by the producer. Accordingly, the investigator, utilizing the energy systems approach, may visualize any economic system as a system of counterbalancing flows: with energy (in the form of raw materials, productive goods and service, or finished goods) flowing in one direction and money in the opposite direction. This result provides two common denominators for the inputs and outputs of any economic system:

1. The money flow associated with the particular input or output;
2. The energy flow (or the work expenditure) associated with the particular input or output.

The dollar flow divided by the energy flow (in heat units) is the average price per unit of energy degraded in order to make the particular energy flow available.

Energy is a rather unique commodity and this uniqueness is very analagous to the unique quality found in currency (or money). Currency possesses its uniqueness because it is a medium of exchange; in other words, all economic goods can be measured in terms of currency units because money values express the relative exchange values of one economic good or service for another economic good or service. Likewise, the energy equivalent measure of the work needed to produce economic goods can serve as a common denominator for describing, relating, comparing, or contrasting various economic goods just as does money. Furthermore, this energy measure can be calculated by considering one or more of the following basic sources of energy: fossil fuel energy, human energy (for either labor or information), and natural energy (which generally requires no money payment for energy from nature in the form of sunlight, natural waste processing, recreation, and such.

NOTES

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2. Hans Thirring, Energy for Man: Windmills to Nuclear Power (Bloomington, Indiana: Indiana University Press, 1958), p. 15-16.

3. Ibid., pp. 16-17.

4. Ibid., pp. 14-15.

5. Mitchell Wilson, Energy (New York: Time-Life Books, 1963), pp. 37-38.

6. John Holdren and Philip Herrera, op. cit., pp. 16-17.

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8. Chauncy Starr, "Energy and Power," Energy and Power--A Scientific American Book (San Francisco: W.H. Freeman and Company, 1971). p. 3.

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13. Ibid., p. 30.

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15. Ibid., p. 4.

16. Roy A. Rappaport, "The Flow of Energy in an Agricultural Society," Energy and Power--A Scientific American Book (San Francisco: W.H. Freeman and Company, 1971), p. 79.

17. Larry D. Singell (Editor), Collected Papers of Kenneth E. Boulding--Volume Three Political Economy (Boulder, Colorado: Colorado Associated University Press, 1973), p. 328.

18. Ibid., p. 328.

19. Ibid., p. 303.

20. Ibid., p. 303-304.

21. Ibid., p. 36 and 153.

22. Ibid., pp. 153-154.

23. Ibid., p. 153.

24. Howard T. Odum, Environment, Power and Society (New York: Wiley-Interscience, 1971), p. 32.

25. Ibid., p. 32-33.

26. Ibid., p. 33.

27. Larry D. Singell (Editor), op. cit., pp. 436-437.

28. Howard T. Odum, op. cit., pp. 174-176.

29. Larry D. Singell (Editor), op. cit., pp. 436-437.

30. Howard T. Odum, op. cit., p. 34.

31. Ibid., p. 45-47.

32. Ibid., p. 34.

33. Ibid., p. 175.

34. Ibid., p. 150-151.

CHAPTER IV
THE GENERAL ENERGY SYSTEMS RATIO OF EXCHANGE MODEL

The discussion of Chapters I and II indicates that many accountants are questioning the interpretation and usefulness of the information communicated via today's financial statements because that information is the result of using acquisition ratios of exchange as valuation coefficients for long-lived productive resource inputs. In the case of the statement of financial position, it is pointed out that measuring long-lived productive resources in terms of historical cost communicates neither the current money cost which would be incurred by an accounting entity to acquire similar service capabilities (reproduction or replacement cost) nor the amount of cash which would be collected if the entity should decide to dispose of the resources (net realizable value). Furthermore, these historical amounts do not reflect the discounted service potential of the resources to the firm, which is the theoretically ideal measurement concept to be used as a valuation coefficient.

In addition, the critics contend that the traditional income figure and its components are probably misleading. When prices change over time, the difference between the revenues earned during any accounting period and the expenses incurred during that same period (with some of the expenses being measured in terms of valuation coefficients based on exchange ratios from earlier accounting periods) does not necessarily provide an accurate indication of the entity's current profit generating capabilities. This result occurs because the traditional profit figure combines the results of management operating activity with the unrecorded results of input resource holding activity during time periods when the prices of input resources are changing. It is believed that better business decisions will be made if the results of holding activities are reported separately from the results of operating activities.

In order to separate operating results from holding results, a method of estimating current ratios of exchange for older style input resources must be developed. This chapter will deal with the development of a price model in terms of general energy systems theory, which will provide estimates of replacement or reproduction ratios of exchange for older style resources by utilizing the readily obtainable market prices for newer styles of similar resources.

The General Energy Systems Currency Exchange Ratio Model

The underlying premise of the general energy systems approach, upon which the energy price model is based, is that energy, in the form of goods and services, flows in the opposite direction to money, the payment mechanism for the goods and services. Therefore, an average price per unit of energy can be determined at any aggregate level desired by simply dividing the dollar flows by the energy flows at that particular level. For the overall U.S. economy this model may be stated as:

$$\text{Average Price Per Unit of Energy for the Economy} = \frac{\text{Sum of all prices times all quantities of goods and services}}{\text{Sum of energy equivalents of all resource inputs used in producing the output of goods and services}}$$

A more general formulation of the general energy systems price model can be mathematically expressed as follows:

$$\text{Estimated Average Price per Unit of Energy for a Long-Lived Productive Resource} = \frac{\Sigma P_i q_i}{\Sigma E_i}$$

Where: P_i = the average price of output i;

q_i = the average quantity of output i;

E_i = the energy equivalents of all the resource inputs utilized to produce q_i.

In order to fully understand the operation of this model it is necessary to examine a hypothetical example. However, before the illustration can be discussed it is necessary to consider another important concept--the concept of economic efficiency.

The Concept of Economic Efficiency

Overall Economic Efficiency.

Overall economic efficiency refers to a system's ability to transform raw materials into the goods and services required by that system. Thus, economic efficiency may change not only because of changes in the efficiency of extracting the heat available to do work from fuels or the efficiency of conversion of heat into a desired form of work, but also because of changes in the structure of output, changes in the overall productive efficiency of the economy, and changes in consumers demand functions.

A change in the structure of output refers to either a change in the relative proportions of the various products produced or a change in the quality of the products produced. A change in the relative proportions of the various outputs may cause some variation in efficiency, because some products require less work per unit to produce than do others. In addition, a product of improved quality generally requires more work to convert the raw materials into the desired finished good than does the lower quality product, assuming constant overall productive efficiency.

The overall productive efficiency of the economy refers to the work flows needed in order to produce the desired outputs, to provide the reinforcing feedback loops to producers, and to support various control structures and activities (for example, the banking system, government systems at all levels, and upper management systems) relative to the quantity of desired outputs produced. In other words, overall productive efficiency is affected by the amount of work which is necessary for the extracting, processing and transporting of raw materials; for the construction and operation of conversion, processing, and transportation facilities; for the transportation, storing, and marketing of finished goods; and for the formation and operation of needed control structures (such as government systems for defense, social stability, regulation to ensure equity for all members of the system, and waste processing to protect natural systems).

A change in the consumer demand function refers to a subjective, social type evaluation of final outputs commonly known in economics as consumer utility or satisfaction. In general, it states that a given output may become either more important or less important to consumers relative to other outputs as time passes. For example, from the biological sciences, it is learned that blood sugar is converted by the human body into various forms of energy. In winter or summer, muscular exertion requires chemical change which also results in energy in the form of high entropy heat. In the winter heat is desirable and may be an end in itself for purposes of warming the body. But in the summer, heat may be undesirable and its reduction is welcomed. So the efficiency of the body in converting food into work would vary from season to season with the change in ends desired.* Therefore, the efficiency of any energy converter may be measured by the proportion of the energy which it has converted into the form desired. For instance, it has been estimated that "somewhat less than 3 percent of the sunlight falling on the U.S. could be converted into other forms of energy by plants.** However, corn, which is believed to have the largest heat-energy return of all man's food crops, stores only about 3/10 of 1 percent of the radiant energy falling on the land where it is grown as actually digestible calories even with a bumper crop."[1] Thus, while the efficiency of plants in utilizing sunlight for their own maintenance as well as for building plant structure is about 3 percent, the efficiency of plants in providing edible plant structure for man is less than 4/10 of 1 percent.

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*This cause of a change in economic efficiency is very interrelated to the change in the structure of output.

**The limits of the use of radiant energy by plants are fixed by the nature of photosynthesis itself which varies with the species as well as with the climate, soil, and so on--in other word, location.

The main point is that without a knowledge of the forms of energy being sought there is no means to determine efficiency. For purposes of this study, it will be assumed that man performs work in order to supply goods and services.* Therefore, overall economic efficiency will be defined as the quantity of energy equivalent measures for the resource inputs needed to produce a particular output relative to the quantity of output produced. It may be computed by multiplying the economic productive efficiency times the relative input transformation efficiency of the goods produced.

Economic Productive Efficiency.

Economic productive efficiency measures the heat value of the input energy degraded in producing the output relative to the quantity of goods and services provided.** An index for measuring it over time is given by the followin formula:

$$P_e = \frac{\Sigma q_{it+j}}{\Sigma E_{it+j}} \div \frac{\Sigma q_{at}}{\Sigma E_{at}}$$

Where: P_e = productive efficiency index;

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*See Chapter I--Assumptions

**In this situation it is not possible to compare the heat value of the goods and services produced because a great majority of work done in the economy is processing work, thus, little, if any, energy is stored.

q_{it+j} = quantity of output goods "i" produced in the current time period t+j;

E_{it+j} = energy equivalents at constant energy quality for all the resources inputs used to produce the output goods in the current time interval t+j;

q_{at} = quantity of output goods "a" (which must be identical to or similar in use to output "i") produced during the base time interval t;

E_{at} = the energy equivalent at constant energy quality for all the resource inputs used to produce the outputs "a" in the base time interval t.

Relative Input Transformation Efficiency of Productive Resources.

The relative input transformation efficiency of productive goods refers to the change in economic efficiency arising out of changes in the quality of output produced in one year relative to output, which has a similar end use, of a previous year. The relative input transformation efficiency of output goods over time intervals, for consumer durables which are made for the purpose of processing energy as well as for capital equipment, is given by the formula:

$$IT_e = \frac{q_{ixt+j}}{E_{ixt+j}} \div \frac{q_{ayt}}{E_{ayt}}$$

Where: IT_e = index of the relative input transformation efficiency of a specified long-lived productive resource over time;

q_{ixt+j} = the quantity of output "i" produced using specified productive resource "x" during the current time interval t+j;

E_{ixt+j} = the energy equivalents at constant energy quality of all the resource inputs needed to produce output "i" with specified productive resource "x" during the current time interval t+j;

q_{ayt} = the quantity of output "a" (which must be identical to or similar in use to output "i") produced by using specified long-lived productive resource "y" (identical to or performing a similar function as productive resource "x" during the base time interval t;

E_{ayt} = the energy equivalent, at constant energy quality, of the resource inputs needed to produce output "a" with specified productive resource "y" during the base time interval t.

At the present time there is no mathematical measure to determine changes in the quality of an output when such output does not itself process energy into other forms of output, but for this study, the major concern is for long-lived productive resources.

Efficiency Concepts and the Ratio of Exchange Model.

A logical inference may be made from the general formulation of the energy systems ratio of exchange model stated above as follows: the average price per unit of energy will vary if either the dollar flow or energy flow varies relative to the other.

While the price for any particular economic good(s) or service(s) is determined by the interactions of supply and demand, its price is constantly changing because both consumer demands and producer's responses to these demands are constantly changing. Implicit in this supply-demand interaction is the notion of output quality--the ability of a particular output to perform the function that it is produced to perform. When the output quality of a given good changes, one should expect the new improved style to be more valuable than its older counterpart because the present value of the sum of future benefits for the newer style will be higher. Therefore, in order to properly evaluate the price change of the older style of a specified long-lived productive resource by analyzing current prices of the newer style, there must be some way to segregate price changes due to changes in economic good quality from price changes caused by the myriad of other factors. In economics this adjustment must be made subjectively as it is extremely difficult to measure quality mathematically. However, for productive resources, energy systems theory provides a measuring technique, described above as the input transformation efficiency. The critical economic assumption which is made in formulating this measure is that the difference in price between two productive resources, identical in all respects except that one is more efficient in performing its function than the other, must be proportional to their difference in efficiencies.

Energy flows vary either because of changes in the productive efficiency of producer units in transforming resource inputs into specified outputs or because of changes in quantity of goods and services needed within a given social system. The effects of changes in the quantity of economic goods and services are implicit in the general energy systems price model. In addition, the mathematical formulation for a measure of productive efficiency is given above. The assumption made in deriving this measure is that the economic system has evolved for the purpose of transforming resource inputs into economic goods and services. Therefore, productive efficiency is the quantity of economic goods and services provided relative to the energy consumed in producing them. It must be stated that productive efficiency may change for any number of reasons; however, there is no need to analyze each of these separately for this particular inquiry. All that is necessary for estimating a current ratio of exchange using general energy systems concepts is the ability to segregate that portion of a change in the price of a specified resource which results from changes in productive efficiency from an overall price change. Moreover, the productive efficiency concept is needed only when it is necessary to estimate the current ratio of exchange for an older style resource via an analysis of prices for newer styles of similar resources.

Implementation of the General Energy Systems Exchange Ratio Model--A Hypothetical Analysis

For purposes of this hypothetical example, both productive efficiency and relative input transformation efficiency will be assumed to be constant. Examples showing the operation of these two concepts in an integrated energy systems approach will be discussed in Chapter V. The implementation of a general energy systems price model will be described in terms of three operational steps: (1) economic data collection and processing, (2) calculation procedures to be performed by the practicing accountant, and (3) the recording and reporting of changes in ratios of exchange.

Economic Data Collection Processing

The first step for making any model operational is the collection of data. The data inputs to the general energy systems ratio of exchange model were discussed in Chapter I. In addition, it was noted that some of the energy flow data is unavailable at the present time. Accordingly, all of the data in the example is hypothetical data constructed for illustrative purposes only. As is the case with most economic data, the dollar flow and the output quantity information is available from many different sources. Unfortunately, the data for identical items is not consistent among all sources. Therefore, the decision must be made as to which source(s) provides the best information.

In addition to the raw data collection, the application of a general energy systems approach to the calculation of an average price per unit of energy input equivalent involves a level of aggregation problem. Stated another way, this problem refers to how specific a particular price per unit of energy must be in order to be useful. For example, the most common expression of an average price per unit of energy input equivalent is the computation of an average price for the whole economy. On the other hand, the most specific calculation is the computation of an average price per unit of energy equivalent for each style of each product which is produced by each entity operating in the economy. The average price per unit of energy for any specific output may vary widely from the average price per unit of energy for the entire economy. However, the computation of an average price per unit of energy at the most micro-economic level possible would require the generation of a huge physical volume of data at a tremendous dollar cost. Accordingly, this writer believes that an appropriate level of aggregation can be formulated somewhere between the two extremes described above. But this problem can only be resolved by empirical research in order to determine particular aggregation groupings that minimize the dispersion of the average price per unit of energy input equivalent for each specific output to be included in a grouping about the average price per unit of energy for an entire grouping combined. The benefit of minimizing this dispersion must be balanced against the higher cost generally associated with increased accuracy (less dispersion about the mean).

A simple hypothetical example may serve to clarify the discussion concerning the aggregation problem. Consider the data shown in Table 4. Assume wheat requires 100,000 BTU's per unit and shirts 250,000 BTU's per unit to produce for each period. The average price per unit of energy input equivalent for both products together for each period is:

for t_o

$$P_{est\ o} = \frac{\Sigma P_{io} q_{io}}{\Sigma E_{io}} = \frac{\$210}{12.5 \times 10^6 \text{ BTU's}}$$

$$= \$.0168 \text{ per thousand BTU's}$$

for t_i

$$P_{est\ 1} = \frac{\Sigma P_{i1} q_{i1}}{\Sigma E_{i1}} \quad \frac{\$310}{11.25 \times 10^6 \text{ BTU's}}$$

$$= \$.0276 \text{ per thousand BTU's}$$

These computations indicate that the average price per unit of energy in the form of the combination of wheat and shirts increased about 65 percent. However, consider the price change of each product individually. A unit of wheat in t_o sold for $1.80 and took 100,000 BTU's to produce

TABLE 4. PRICE AND QUANTITY INDICES

For time t_o	q	P	q P
Wheat	50	$1.80	$ 90
Shirts	30	4.00	120
TOTAL			$210

For time t_1	q	P	q P
Wheat	100	3.00	$300
Shirts	5	2.00	10
TOTAL			$310

Source: Kenneth Boulding, Economic Analysis--Volume II (New York: Harper and Row, 1966), p. 24.

for an average price of \$.018 per thousand BTU's. A shirt in t_0 sold for \$4.00 and required 250,000 BTU's to produce for an average price of \$0.016 per thousand BTU's. But in period t_1 a unit of wheat sold for \$3.00 for an average price of \$.03 per thousand BTU's, and a shirt sold for \$2.00 for an average price of \$.008 per thousand BTU's. Therefore, the average price per unit of energy for both products combined increased by 65 percent, while the average price per unit of energy used to produce wheat increased by 67 percent and the average price per unit of energy used to produce shirts declined by 50 percent. This apparent distortion occurs because during the interval t_0, 60 percent of the energy used for the production of these two products combined was used for the production of shirts--the product with the lowest price per thousand BTU's. Thus, the average price per thousand BTU's for both products was slightly less than the simple average of the energy price for the two products. On the other hand, during time interval t_1 the product mix changes such that 89 percent of the energy used for both products was used to produce the higher priced product--wheat. Therefore, the average price per unit of energy for both products combined was skewed in the direction of the higher priced product. Any calculation of an overall average price per unit of energy equivalent for a grouping of heterogeneous outputs may be distorted by product mix changes, when there is a wide dispersion of the average price per unit of energy for each specific output included in the grouping about the overall average price per unit of energy for the entire group of outputs combined. Therefore, it is desirable to group or aggregate specific outputs in such a manner that the dispersion is minimized. One preliminary proposition advanced in the case of long-lived resources is that the average price per unit of energy equivalent for a resource to be used for a specified purpose is logically expected to be approximately equal to the average price per unit of energy equivalent for all other resources which can be used for similar purposes. The analytical reasoning underlying such a conclusion may be expressed as follows: if this expected end result is not the case, free market competition is expected to result in resource inputs being diverted from the production of the long-lived resource which is priced at a low price per unit of energy input equivalent relative to the others to be used to produce the long-lived resources which are priced at a high price per unit of energy equivalent relative to the others. This process is expected to continue until the average prices per unit of energy equivalent for all substitutable long-lived resources are approximately equal. It must be noted, however, that this form of logical reasoning cannot result in a warranted conclusion without empirical verification.

The many sources of economic data in combination with the fact that each source may report information inconsistent with each other source and the statistical problems inherent in determining the level of aggregation leads to the conclusion that this first step could best be undertaken at the professional level--perhaps by a special AICPA committee. It is believed that the gathering of the raw input data, the statistical determination of the level of aggregation necessary, the computation of the empirical measure for both productive efficiency and input transformation efficiency, as well as the calculation of the average ratio of exchange per unit of energy input equivalent for each category of resources at the professional level, will serve to both reduce cost and provide more objective and accurate data. Table 5 illustrates the proposed hypothetical output of such a committee for two years (1974 and 1978).* In this example the information is classified consistent with the standard industrial classification system used by the Board of Governors of the Federal Reserve System when computing the index of industrial

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*The calculations may be performed and published as frequently or infrequently as is deemed necessary given the degree of accuracy desired as contrasted with the cost associated with accuracy. See Appendix A for a discussion of the procedures followed in calculating the average ratio of exchange per unit of energy.

TABLE 5. ILLUSTRATION OF THE OUTPUT OF A SPECIAL COMMITTEE FORMED TO COLLECT AND CALCULATE ECONOMIC RATIO OF EXCHANGE DATA UTILIZING GENERAL ENERGY SYSTEMS THEORY

Resource Classification	Average Price Per Thousand BTU's of Energy Input Degraded for Providing Resources as Classified		Productive Efficiency Measurement	Input Transformation Efficiency
	1974	1978	1974 and 1978	1974 and 1978
Building and Mining Equipment	.015	.018	1.00	1.00
Oil and gas drilling	.008	.010	1.00	1.00
Tracklaying tractors				
Construction and mining machinery	.030	.025	1.00	1.00
Manufacturing Equipment				
Materials handling machinery	.002	.010	1.00	1.00
Metalworking machinery	.054	.030	1.00	1.00
Special industry machinery	.010	.020	1.00	1.00
General industrial equipment	.045	.035	1.00	1.00
Power Equipment				
Boiler shop products	.033	.020	1.00	1.00
Turbines	.013	.045	1.00	1.00
Electrical distribution equipment	.024	.030	1.00	1.00
Commercial Equipment				
Fixtures and office furniture	.050	.040	1.00	1.00
Office and computing machines	.034	.040	1.00	1.00
Service industry equipment	.042	.030	1.00	1.00

TABLE 5 - CONTINUED

Resource Classification	Average Price Per Thousand BTU's of Energy Input Degraded for Providing Resources as Classified		Productive Efficiency Measurement	Input Transformation Efficiency
	1974	1978	1974 and 1978	1974 and 1978
Commercial Equipment (Con't)				
Telephone apparatus	.062	.055	1.00	1.00
Scientific and optical goods	.150	.090	1.00	1.00
Medical instruments	.095	.075	1.00	1.00
Transit Equipment				
Trucks and buses	.006	.010	1.00	1.00
Truck trailers	.012	.020	1.00	1.00
Commercial aircraft	.034	.040	1.00	1.00
Commercial aircraft equipment	.029	.030	1.00	1.00
Commercial ships	.017	.015	1.00	1.00
Railroad equipment	.005	.009	1.00	1.00
Farm Equipment				
Farm machinery	.007	.009	1.00	1.00
Farm tractors	.002	.006	1.00	1.00
Construction Products				
Stone, sand, gravel	.006	.010	1.00	1.00
Lumber	.004	.015	1.00	1.00
Millwork	.012	.020	1.00	1.00
Plywood and prefab products	.018	.022	1.00	1.00
Building paper and board	.020	.030	1.00	1.00

TABLE 5 - CONTINUED

Resource Classification	Average Price Per Thousand BTU's of Energy Input Degraded for Providing Resources as Classified		Productive Efficiency Measurement	Input Transformation Efficiency
	1974	1978	1974 and 1978	1974 and 1978
Construction Products (Con't)				
Construction paints	.035	.030	1.00	1.00
Paving and roofing materials	.040	.045	1.00	1.00
Construction glass	.025	.035	1.00	1.00
Brick	.008	.015	1.00	1.00
Clay, firebrick, pipe and tile	.012	.020	1.00	1.00
Construction pottery products	.045	.050	1.00	1.00
Concrete and plaster products	.038	.060	1.00	1.00
Construction steel	.028	.045	1.00	1.00
Plumbing and heating products	.042	.050	1.00	1.00
Structural metal	.039	.060	1.00	1.00
Lighting and wiring products	.055	.040	1.00	1.00
Construction Labor	.150	.180	1.00	1.00
Fossil Fuels				
Gasoline	.020	.025	1.00	1.00
Fuel Oil	.021	.028	1.00	1.00
Diesel fuel	.018	.026	1.00	1.00
Other	.022	.023	1.00	1.00

production for the U.S.* It cannot be overemphasized that this example in no way suggests that this classification scheme is to be preferred over any others. Any conclusions concerning classification can only be stated after additional empirical research has been completed.

Calculation Procedures for the CPA

It is also necessary to discuss this second step for implementing the energy systems ratio of exchange model in terms of a hypothetical case. For example, assume company A builds a large production facility in 1974. As stated above, the accounting problem for 1975, as well as for all future time intervals until the end of the useful life of the facility, is to determine both the currency value of the service capabilities utilized during each accounting period and the currency value of the future service capability remaining at the end of each accounting period. It has been assumed that financial statement users desire valuation coefficients based on current ratios of exchange as opposed to those based on acquisition ratios of exchange.** Therefore, in the example being formulated here, the financial information desired for a future year, such as 1978, must be calculated based on the ratios of exchange prevailing in 1978. However, there may not be any productive resources identical in every respect to company A's productive facility being sold or exchanged in 1978. But, when it is realized that A's productive facility is an organized set of many component parts (such as machines, belts, and buildings), it becomes obvious that there is a likelihood that components similar, if not identical, to the component parts of A's facility will be produced and sold in 1978. The first step of implementing the general energy system model described above showed that a professional committee would be responsible for gathering economic data concerning market transactions for these component resources. Furthermore, this data would be grouped according to a particular level of aggregation scheme previously decided and an average price per unit of energy input equivalent would be calculated for each grouping. In addition, an index of average productive efficiency and an index of average input transformation efficiency will be calculated for each grouping.* The second step will describe how managerial accountants independent auditors, and others responsible for valuation of resources can use the data generated by the professional committee to estimate the current reproduction or replacement exchange ratio of a long-lived productive facility acquired during an accounting period.

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*How many classifications are to be reported depends upon how specific the average ratios of exchange must be.

**See Chapter I--Assumptions.

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*Hypothetical output from such procedures is depicted in Table 5.

Consider company A's facilities when they are constructed in 1974. At this time, it is necessary for the measurer to carefully classify all of the dollar expenditures incurred to acquire the facilities in terms of the various classifications used by the AICPA committee in reporting the average prices per thousand BTU's of energy input equivalent. For example, assume the facilities require the expenditures shown in colume one of Table 6 for the various resources. The total capitalized cost of A's facilities equals $6,000,000 which is allocated into classications corresponding to those shown in Table 5. Now, the energy equivalent of the input resources degraded in producing A's manufacturing facilities may be computed by dividing the dollar expenditures for each classification by the average price per thousand BTU's of energy input equivalent for the same classifications as reported in Table 5. The third column of Table 6 shows the energy equivalents for the resource inputs used to construct company A's facilities. The energy equivalents for all of the inputs used in constructing A's facilities total 489.9×10^9 BTU's. Dividing the $6,000,000 cost by 489.9×10^9 BTU's given an average price of $.0122 per thousand BTU's for the entire productive facility. The last two columns of Table 6 show that this same result may be obtained by calculating a weighted average of the prices per unit of input equivalent for each resource classification, where the weight for each individual price

TABLE 6. CALCULATIONS MADE BY AN ACCOUNTANT IN IMPLEMENTING THE GENERAL ENERGY SYSTEMS RATIO OF EXCHANGE MODEL

Resource Classification	Column 1[a]	Column 2[b]	Column 3[c]	Column 4[d]	Column 5[e]
Material hand. equip.	$ 500,000	.002	250.0 x 10^9 BTU's	51.0	.0010
Special ind. mach.	1,000,000	.010	100.0 x 10^9 BTU's	20.4	.0020
Elect. dist. equip.	150,000	.024	6.3 x 10^9 BTU's	1.3	.0003
Fixtures and off. furn.	250,000	.050	5.0 x 10^9 BTU's	1.0	.0005
Office and comp. mach.	200,000	.034	5.9 x 10^9 BTU's	1.2	.0004
Telephone apparatus	50,000	.062	.9 x 10^9 BTU's	.1	.0001
Lumber	20,000	.004	5.0 x 10^9 BTU's	1.2	.0001
Plywood and pre. prod.	50,000	.018	2.8 x 10^9 BTU's	.6	.0001
Construction paints	30,000	.035	.9 x 10^9 BTU's	.1	.00007
Paving and roof. mat.	300,000	.040	7.5 x 10^9 BTU's	1.5	.0006
Bricks	100,000	.008	12.5 x 10^9 BTU's	2.6	.0002
Clay, etc.	150,000	.012	12.5 x 10^9 BTU's	2.6	.0003
Concrete, etc.	800,000	.038	21.1 x 10^9 BTU's	4.3	.0016
Construction steel	400,000	.028	14.3 x 10^9 BTU's	2.9	.0008
Plumbing, etc.	150,000	.042	3.6 x 10^9 BTU's	.7	.0003
Lighting, etc.	250,000	.055	4.6 x 10^9 BTU's	.9	.0005
Gasoline	600,000	.020	30.0 x 10^9 BTU's	6.1	.0012
Construction labor	1,000,000	.150	7.0 x 10^9 BTU's	1.4	.0021
TOTAL	$6,000,000		489.9 x 10^9 BTU's	100.0	.0122

[a] Column 1 - Dollar Cost

[b] Column 2 - 1974 Average Price Per Thousand BTU's of Energy

[c] Column 3 - Energy Equivalents of Inputs Degraded in Producing A's Facilities

[d] Column 4 - Percent of Total Weight

[e] Column 5 - The Contribution of Each Classification to the Total Plant Average Price Per Thousand BTU's of Energy Equivalent Input

is the energy contribution of each classification relative to the total energy equivalent for the facilities. Therefore, in 1978 the average price per unit of energy input equivalent for the entire facility may also be computed by calculating a weighted average of the average price per unit of energy for each group of resource inputs used in constructing the facilities. This computation is illustrated in Table 7.

The timing of the release of services to accounting time intervals may be done by applying any of the arbitrary depreciation methods currently accepted to the energy input equivalent measure for the long-lived productive resource. For example, assume company A's facilities are expected to have a useful life of ten years and the straight line method of depreciation is adopted. Each year, from 1974 to 1984, the currency value of 48.99 x 10^8 BTU's of energy equivalents in the form of company A's production unit structure will be included as a depreciation expense. Thus, for 1978 the depreciation expense would be about \$1,040,000 (48.99 x 10^9 BTU's x \$.2123 per thousand BTU's). The replacement cost of the remaining service potential of the resource at the end of 1978 would total approximately \$5,200,000. This amount is determined by multiplying the 1978 energy equivalent measure of the resource times the average energy exchange ratio for resource inputs of the type employed in constructing the long-lived resource (244.95 x 10^9 BTU's x \$.02123 per thousand BTU's).

TABLE 7. COMPUTATION OF THE AVERAGE PRICE PER UNIT OF ENERGY INPUT EQUIVALENT FOR COMPANY A'S 1974 MANUFACTURING FACILITIES FOR THE YEAR 1978

Resource Classification	Energy Equivalent Weights	1978 Average Price Per Thousand BTU's of Energy Input Equivalent	Average Price Per Thousand BTU's for for A's Facilities Computed by Weighting Individual Avg. Prices
Material hand. equipment	.51	.010	.0051
Special ind. mach.	.204	.020	.0041
Elec. dist. equipment	.013	.030	.0004
Fixtures and office furniture	.010	.040	.0004
Office and comp. mach.	.012	.040	.0005
Telephone apparatus	.001	.055	.0001
Lumber	.012	.015	.0002
Plywood and pre. prod.	.006	.022	.0001
Construction paints	.001	.030	.0003
Paving and roof. materials	.015	.045	.0007
Bricks	.026	.015	.0004
Clay, etc.	.026	.020	.0005
Concrete, etc.	.043	.060	.0026
Cosntruction steel	.029	.045	.0013
Plumbing, etc.	.007	.050	.0004
Lighting, etc.	.009	.040	.0004
Gasoline	.061	.025	.0015
Construction labor	.014	.180	.0025
Total			.02123

Recording and Reporting Financial Results.

The recording and reporting of financial results, problems which stem from changes in the ratios of exchange computed using the general energy systems, approach, are identical to the problems encountered using any other method which proposes valuation coefficients based on ratios of exchange other than acquisition cost. A complete discussion of the appropriate journal entries and financial reports is found in either *The Theory and Measurement of Business Income* by Edwards and Bell or *Replacement Cost Accounting* by Lawrence Revsine.

NOTES

1. Hans Thirring, *Energy for Man: Windmills to Nuclear Power* (Bloomington, Indiana: Indiana University Press, 1958), p. 63.

CHAPTER V
THE GENERAL ENERGY SYSTEMS PRICE MODEL--AN EVALUATION OF ITS USEFULNESS FOR DETERMINING VALUATION COEFFICIENTS FOR USE IN ACCOUNTING

Having developed and described the energy system exchange ratio estimation model, the next step is to evaluate this model. As was stated in Chapter I, evaluation will be in terms of the various criticisms of previously proposed methods for converting acquisition cost to current cost. These criticisms are expressed in terms of the ends-in-view necessary to resolve the tensions currently observed among the accountants who are charged with communicating financial information when measurement of long-lived productive resources is a necessary part of this task. The ends-in-view are then modified to the form of general hypotheses for purposes of evaluation. These hypotheses are restated as follows:

1. *The conceptual framework of the general energy systems approach is logically consistent.*

2. *The general energy systems approach provides accurate estimates of the current reproduction (or replacement) cost of a specified long-lived productive resource.*

3. The energy systems approach for estimating current replacement or reproduction cost can be made operational such that there is a reasonable empirical correlation between the estimates provided even when different groups of observers apply the measurement procedures in generating estimates.

However, as was also stated in Chapter I, data limitations with respect to the quantity of resource inputs, measured in terms of energy heat equivalents, necessary to construct long-lived productive resources will significantly restrict empirical analysis. This limitation, in turn, will prevent "warranted conclusions" from this evaluation. However, it is felt that significant insight may be obtained with respect to the analytical soundness of a general energy systems approach for accounting for long-lived productive resources. In addition, the direction of future empirical inquiry may be obtained as a result of this preliminary evaluation.

The Question of Logical Consistency--An Evaluation

In order to draw conclusions concerning the logical consistency of a general energy systems ratio of exchange estimation model, it is necessary to consider two aspects of the problem, which may be stated in the form of subhypotheses as follows:

1. The general energy systems model is internally consistent.

2. The price estimates obtained via applying the general energy systems model are consistent with currently accepted economic price theory.

In order to properly evaluate these two aspects of the logical consistency question, it is necessary to formulate some hypothetical economic situations. In addition to providing the means of evaluating the logical consistency of general energy systems theory, these hypothetical examples will further illustrate the mechanical procedures involved in applying general energy systems theory to the long-lived resource accounting problem.

Two basic hypothetical examples will be proposed; various modifications will then be made to each in order to consider the applicability of the model in various economic environments. The first example will exclude changes in the efficiency of a productive resource for performing its designated task (i.e. input transformation efficiency will be assumed to remain unchanged over time); the second example will introduce this problem.

Example One--Steady State Input Transformation Efficiency

Assume that all U.S. producers of a specified long-lived productive resource produce 2000 units of this resource for a price of $1,000 per unit each year from 1960 to 1970.

The economic price index for the specified resource will reflect only changes from the $1,000 per unit prices which prevailed in 1960; the output index will reflect only changes from the 2000 units of output produced in 1960.

Case 1--Steady state. For Case 1, additional assumptions are made as follows: (1) productive efficiency does not change from 1960 to 1970, thus there is a constant quantity of resource inputs (measured at 100 x 10^9 BTU's in constant energy equivalent units); (2) no changes in the economic price index; (3) all units produced from 1960 to 1970 are identical in all respects; and (4) these long-lived productive resources never wear out. This situation may be summarized in terms of national income statistics as follows:

	Specific Economic Price Index	Specific Output Index
1960	100	100
1965	100	100
1970	100	100

If company A buys two units of the long-lived resource in 1960 and company B buys two units in 1965, what would be their respective valuation coefficients for 1970 as measured with reference to their 1970 replacements ratios of exchange determined via energy systems theory? The first step is to calculate the energy ratios of exchange for the resources purchased in each year in the following manner:

$$P_{est} = \frac{q_i P_i}{E_i}$$

1960 energy exchange ratio = (2000 units x \$1,000 per unit) ÷ (100,000 BTU's) = \$.02 per thousand BTU's

1965 energy exchange ratio = \$.02 per thousand BTU's

1970 energy exchange ratio = \$.02 per thousand BTU's

As noted in Chapter IV, it is felt that this calculation should be made by a professional committee of the AICPA.

This step is followed by computing the energy equivalents of the resources purchased by each company as shown below:

Energy Equivalents = (Purchase price paid by each company) ÷ the energy exchange ratio in the year of purchase

Company A = (2 units at \$1,000 per unit) ÷ \$.02 per thousand BTU's = 100×10^6 BTU's

Company B = \$2,000 ÷ \$.02 per thousand BTU's = 100×10^6 BTU's

The third step is to subtract the energy equivalents allocated to various time intervals from the total determined in Step Two to obtain the unexpired energy equivalents. In this hypothetical case, the productive resources never wear out, so this step may be eliminated.

The final step is to determine the currency value of the unexpired resource by multiplying the unexpired energy equivalents computed in Step Three by the current accounting period's energy exchange ratio for the same productive resource (or its replacement in terms of desired end use). This is done as follows:

Company A: 100×10^6 BTU's x \$.02 per thousand BTU's = \$2,000

Company B: 100×10^6 BTU's x \$.02 per thousand BTU's = \$2,000

Since the two resources are identical in all respects and never wear out, one would logically expect their prices to be identical in terms of the 1970 currency values. This is indeed the result obtained by applying the general energy systems model. Moreover, the 1970 values are identical to the original acquisition values which is to be expected as the economic price index shows prices for the resource have not changed over time and productive efficiency was assumed constant in this case (i.e. the energy flow necessary to produce the resource remains constant over time).

Case II--Inflation. For Case II, further assumptions are made as follows: (1) productive efficiency remains constant from 1960 to 1970, thus the energy equivalents of resource inputs remain constant at 100×10^9 BTU's each year; (2) the price of the productive resources produced increases from \$1,000 per unit in 1960 to \$1,100 per unit in 1965 and 1970; (3) the units produced from 1960 to 1970 are identical in all respects; and (4) they never wear out. This situation is summarized as follows:

	Economic Price Index	Output Index
1960	100	100
1965	110	100
1970	110	100

Again, if company A buys two units of the long-lived resource in 1960 and company B buys two units in 1965, what would be their respective valuation coefficients in 1970 determined via energy systems analysis? The ratio of exchange per unit of energy input for each year is:

1960 = (2000 units x \$1,000 per unit) ÷ (100 x 10^9 BTU's) = \$.02 per thousand BTU's

1965 = (200 units x \$1,100 per unit) ÷ (100 x 10^9 BTU's) = \$.022 per thousand BTU's

1970 = \$.022 per thousand BTU's

The energy equivalents of the resources purchased by each company are:

Company A = (2 units at \$1,000 per unit) ÷ \$.02 per thousand BTU's = 100 x 10^6 BTU's

Company B = (2 units at \$1,100 per unit) ÷ \$.022 per thousand BTU's = 100 x 10^6 BTU's

Since these energy equivalents would be worth \$.022 per thousand BTU's in 1970, the currency value of the unexpired resource is \$2,200 to each company given that each company owns unexpired benefits which would require 100 x 10^6 BTU's of resource inputs to replace in 1970. Again, this result is identical to the results expected given currently accepted economic price theory.

Case III--Deflation. This hypothetical situation is identical to Case II except that prices for the specified long-lived productive resource fall to \$900 by 1965. This situation may be depicted as follows:

	Specific Economic Price Index	Specific Output Index
1960	100	100
1965	90	100
1970	90	100

The ratio of exchange per unit of energy input for each year is:

1960 = (2000 units x \$1,000 per unit) ÷ 100 x 10^9 BTU's = \$.02 per thousand BTU's

1965 = (2000 units x \$900 per unit) ÷ 100 x 10^9 BTU's = \$.018 per thousand BTU's

1970 = \$.018 per thousand BTU's

The energy equivalents of the resources purchased by each company are:

Company A = (2 units at \$1,000 per unit) ÷
\$.02 per thousand BTU's =
100×10^6 BTU's

Company B = (2 units at \$900 per unit) ÷
\$.018 per thousand BTU's =
100×10^6 BTU's

Therefore, the currency value of the unexpired energy equivalents in 1970 are:

Company A = 100×10^6 BTU's x \$.018 per thousand BTU's
= \$1,800

Company B = 100×10^6 BTU's x \$.018 per thousand BTU's
= \$1,800

Again, this result is identical to that which would be expected given currently accepted economic price theory.

Case IV--Varying productive efficiency. For Case IV, the following additional assumptions are made: (1) the price of the long-lived productive resource remains constant at \$1,000 per unit from 1960 to 1970; (2) productive efficiency changes such that 100×10^9 BTU's are required in 1960, 80×10^9 in 1965, and 70×10^9 in 1970; (3) all units produced from 1960 to 1970 are identical in all respects and they will never wear out. The economic indicators are as follows:

	Specific Economic Price Index	Specific Output Index
1960	100	100
1965	100	100
1970	100	100

The ratio of exchange per unit of energy for each year is:

1960 = (2000 units x \$1,000 per unit) ÷ 100×10^9 BTU's = \$.02 per thousand BTU's

1965 = (2000 units x \$1,000 per unit) ÷ 80×10^9 BTU's = \$.025 per thousand BTU's

1970 = (2000 units x \$1,000 per unit) ÷ 70×10^9 BTU's = \$.02857 per thousand BTU's

The energy equivalents of the resources purchased by each company are:

Company A = (2 units at \$1,000 each) ÷ \$.02 per thousand BTU's = 100×10^6 BTU's

Company B = (2 units at \$1,000 each) ÷ \$.025 per thousand BTU's = 80×10^6 BTU's

However, at this point an inconsistency becomes apparent. If these energy equivalents are converted into currency valuation coefficients by multiplying by the 1970 ratio of exchange per unit of energy, company A's resource will be valued at \$2,875 while company B's will be valued at \$2,285.60. Yet, these two resources are identical in all respects. Accordingly, such a result is inconsistent with economic price theory. Therefore, it is necessary to correct for this inconsistency by restating energy equivalents into units of constant productive efficiency. This is accomplished by using the productive efficiency index to restate an older resource's energy equivalents in terms of the quantity of resource inputs that it would currently take to duplicate the given resource. It is felt that the professional committee should be responsible for constructing the productive efficiency indexes, as well as calculating the energy exchange ratios. Thus, as part of the first step of computing replacement exchange ratios using an energy systems approach, it is necessary to also calculate a productive efficiency index for each year as follows:

$$\text{Productive efficiency index} = P_{ej} = \frac{q_{it+j}}{E_{it+j}} \div \frac{q_{at}}{E_{at}}$$

$$\begin{aligned}
1960 &= (2000 \text{ units} \div 100 \times 10^{9} \text{ BTU's}) \div \\
&\quad (2000 \text{ units} \div 100 \times 10^{9} \text{ BTU's}) = 1.00 \\
1965 &= (2000 \text{ units} \div 80 \times 10^{9} \text{ BTU's}) \div \\
&\quad (2000 \text{ units} \div 100 \times 10^{9} \text{ BTU's}) = 1.25 \\
1970 &= (2000 \text{ units} \div 70 \times 10^{9} \text{ BTU's}) \div \\
&\quad (.02 \times 10^{-6}) = 1.42855
\end{aligned}$$

Using the productive efficiency index it is possible to restate the unexpired energy equivalents for the older style resources in terms of the current year's productive efficiency as follows:*

$$\text{Energy Equivalents Restated for Constant Productive Efficiency} = \text{Energy Equivalents for the Resources Purchased by Each Company} \times \frac{P_{ej1} \text{ in the year of purchase}}{P_{ej2} \text{ in the current year}}$$

Therefore, the restated energy equivalents for each company in 1970 are:

$$\text{Company A} = 100 \times 10^6 \text{ BTU's} \times \frac{1.00}{1.42855} =$$
$$700 \times 10^6 \text{ BTU's}$$
$$\text{Company B} = 80 \times 10^6 \text{ BTU's} \times \frac{1.25}{1.42855} =$$
$$700 \times 10^6 \text{ BTU's}$$

The currency values for the unexpired reqources owned by each company in 1970 are 700×10^6 BTU's x \$.02857 per thousand BTU's = \$2,000. This result is again consistent with economic price theory, because resources identical in all respects are expected to have the same currency value. Moreover, the current year's values are expected to be equal to the acquisition value because the original energy equivalents are restated in terms of the current period's productive efficiency which means the decline in the number of energy equivalents is proportional to the increase in price per BTU, thus leaving the value unchanged over time.

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*For a complete discussion of this index see Page 112-113.

Example Two--Varying Transformation Efficiency

In this hypothetical situation is is assumed that producers of a specified long-lived resource produce 2000 units per year from 1960-1970 and that such output sold for $1,000 per unit in 1960. Company A purchases two units in 1960 and Company B two units in 1965.

Case I--Varying prices, productive efficiency, and input transformation efficiency. In addition, the following will be assumed: (1) production of the 2000 units of output required input resources of 100×10^9 BTU's in 1960 and 125×10^9 BTU's in both 1965 and 1970; (2) both the 1965 and the 1970 output is sold for $1,250 per unit; (3) none of the units produced ever wear out; (4) technological advancements result in the 1965 output being a higher quality productive resource than the 1960 output--that is, the net present value of future cash flow was higher for the units produced in 1965 relative to the units produced in 1960, because utilization of the resources produced in 1965 allows five units of output to be produced per 160×10^6 BTU's of resource inputs whereas the units produced in 1960 manufacture only four units of output per 160×10^6 BTU's of input; and (5) no additional technological advances were made from 1965 to 1970.

This example may be summarized as follows:

	Specific Economic Price Index	Specific Output Index
1960	100	100
1965	125	100
1970	125	100

The ratio of exchange per unit of energy for each year is:

1960 = (2000 units x \$1,000 per unit) ÷ 100×10^9 BTU's = \$.02 per thousand BTU's

1965 = (2000 units x \$1,250 per unit) ÷ 125,000 BTU's = \$.02 per thousand BTU's

1970 = \$.02 per thousand BTU's

Productive efficiency for each year is:

1960 = (2000 units ÷ 100×10^9 BTU's) ÷ (2000 units ÷ 100×10^9 BTU's) = 1.00

1965 = (2000 units ÷ 125×10^9 BTU's) ÷ $(.02 \times 10^{-6})$ = .80

1970 = .80

The energy equivalents of resources purchased by each company are:

Company A = (2 units at \$1,000 per unit) ÷ \$.02 per thousand BTU's = 100×10^6 BTU's

Company B = (2 units at \$1,250 per unit) ÷ \$.02 per thousand BTU's = 125×10^6 BTU's

The energy equivalents restated for productive efficiency are:

$$\text{Company A} = 100 \times 10^6 \text{ BTU's} \times \frac{1.00}{.80} = 125 \times 10^6 \text{ BTU's}$$

$$\text{Company B} = 125 \times 10^6 \text{ BTU's} \times \frac{.80}{.80} = 125 \times 10^6 \text{ BTU's}$$

At this point an inconsistency becomes apparent. The currency based replacement value for each company's resources would be equal, but company B owns a technologically superior long-lived productive resource. Therefore, economic price theory would demand that the superior resource command a higher price. In fact, if the economic exchange system is functioning properly and if the older resource is competitive with the newer, superior one over the long run, the difference in price between the two should be proportional to the difference in quality. Accordingly, another adjustment, using an index of the relative input transformation efficiency of productive goods, must be made as follows:*

$$\begin{array}{l}\text{Index of the relative}\\ \text{input transformation}\\ \text{efficiency of}\\ \text{producer goods}\end{array} = IT_{ej} = \frac{q_{ixt+j}}{E_{ixt+j}} = \frac{q_{ayt}}{E_{ayt}}$$

The computation of this index should also be the responsibility of the AICPA committee. The index of relative input transformation efficiency of the producer goods in this example is:

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*For a complete discussion of the relative input transformation efficiency of a productive resource see Page 113-115.

$$1960 = \frac{4 \text{ units} \div 160 \times 10^{6} \text{ BTU's of resource inputs}}{5 \text{ units} \div 160 \times 10^{6} \text{ BTU's of resource inputs}}$$

$$= .8$$

$$1965 = \frac{.02 \times 10^{-6} \text{ units per BTU}}{.02 \times 10^{-6} \text{ units per BTU}} = 1.0$$

$$1970 = 1.0$$

The energy equivalents restated for productive efficiency are then further restated for input transformation efficiency by the following formula:

$$\begin{array}{l}\text{Energy Equivalents}\\ \text{Restated for Input}\\ \text{Transformation}\\ \text{Efficiency}\end{array} = \begin{array}{l}\text{Energy Equivalents}\\ \text{Restated for}\\ \text{Productive}\\ \text{Efficiency}\end{array} = \frac{IT_{ej1} - IT_{ej} \text{ in the year of purchase}}{IT_{ej2} - IT_{ej} \text{ for the most recent year}}$$

$$\text{Company A} = 125 \times 10^{6} \text{ BTU's} \times \frac{.8}{1.0} = 100 \times 10^{6} \text{ BTU's}$$

$$\text{Company B} = 125 \times 10^{6} \text{ BTU's} \times \frac{1.0}{1.0} = 125 \times 10^{6} \text{ BTU's}$$

Converting these energy equivalents to currency replacement values yields a $2,000 value to company A's resources and $2,500 to company B's. This result is consistent with economic theory as company B's productive resources produce 25 percent more output per unit of resource input than company A's resources. Therefore, assuming equal prices for all resource inputs and all output, the net present value of future cash flows would be 25 percent higher for B's resources than for A's.

Case II--Varying productive efficiency and input transformation efficiency and continuing inflation. For Case II, additional assumptions are made as follows: (1) production of the 2000 units requires 100 x 10^9 BTU's in 1960 and 125 x 10^9 BTU's in both 1965 and 1970; (2) the output is sold for $1,100 per unit in 1965 and for $1,200 per unit in 1970; (3) none of the units produced ever wear out; (4) technological advancements have made the units produced in 1965 more efficient than those produced in 1960 in that those produced in 1965 and 1970 manufacture six units of output per 160 x 10^6 BTU's of input versus four units per 160 x 10^6 BTU's for the units produced in 1960; (5) no further technological advancements were made from 1965 to 1970. This situation may be summarized as follows:

	Economic Price Index	Output Index
1960	100	100
1965	110	100
1970	120	100

The ratio of exchange per unit of energy in this form for each year is:

1960 = (2000 units x $1,000 per unit) ÷ 100 x 10^9 BTU's = $.02 per thousand BTU's

1965 = (2000 units x \$1,100 per unit) ÷ 125 x 10^9
BTU's = \$.0176 per thousand BTU's

1970 = (2000 units x \$1,200 per unit)   125 x 10^9
BTU's = \$.0192 per thousand BTU's

Productive efficiency for each year is:

1960 = (2000 units ÷ 100 x 10^9 BTU's) ÷ (2000 units
÷ 100 x 10^9 BTU's) = 1.00

1965 = (2000 units ÷ 125 x 10^9 BTU's) ÷
(.02 x 10^{-6}) = .80

1970 = .80

The relative input transformation efficiency of each year's output is:

$$1960 = \frac{4 \text{ units} \div 160 \times 10^6 \text{ BTU's of resource inputs}}{6 \text{ units} \div 160 \times 10^6 \text{ BTU's of resource inputs}}$$

= .6667

$$1965 = \frac{6 \text{ units} \div 160 \times 10^6 \text{ BTU's of resource inputs}}{6 \text{ units} \div 160 \times 10^6 \text{ BTU's of resource inputs}}$$

= 1.0

1970 = 1.0

The energy equivalents of resources purchased by each company are:

Company A = (2 units at \$1,000 each) ÷
\$.02 per thousand BTU's =
100 x 10^6 BTU's

$$\text{Company B} = (2 \text{ units at } \$1{,}100 \text{ each}) \div \$.0176 \text{ per thousand BTU's} = 125 \times 10^6 \text{ BTU's}$$

The unexpired energy equivalents of resources purchased by each company restated for both productive efficiency and relative input transformation efficiency of productive goods are as follows:

$$\text{Company A} = 100 \times 10^6 \text{ BTU's} \times \frac{1.00}{.80} \times \frac{.667}{1.0} = 83.3 \times 10^6 \text{ BTU's}$$

$$\text{Company B} = 125 \times 10^6 \text{ BTU's} \times \frac{.8}{.8} \times \frac{1.0}{1.0} = 125 \times 10^6 \text{ BTU's}$$

The 1970 currency value for the two units owned by company A is 83.3×10^6 BTU's x \$.0192 per thousand BTU's = \$1,600; the currency value for the two units owned by company B is 125×10^6 BTU's x \$.0192 per thousand BTU's = \$2,400. This is consistent with economic price theory because each unit produced in 1970 cost \$2,400 and the units produced that year are more efficient than those produced in 1960. Therefore, the price for each unit produced in 1960 should vary from the price of those units produced in 1970 proportionately to the difference in efficiency.

In each of the above hypothetical cases, the energy systems procedures have been shown to be consistent with currently accepted economic price theory (i.e. resources identical in all respects except for the year they were produced are assigned equal currency values). In addition, the procedures are internally consistent in the sense that changing economic environments can be properly handled.

Estimated Ratios of Exchange Accurately Reflect Actual Current Ratios of Exchange--An Evaluation

As was stated in Chapter I, "accurate" is a term which refers to the degree of empirical correspondence between an estimated measure for a specified object and some ideal measure of this same object. In economics, the ideal measurement for the currency value of a long-lived productive resource is the net present value of the future benefits to be obtained via ownership of such resources. It was also stated in Chapter I that the market price for a long-lived productive resource in a perfectly competitive market is assumed to be equal to the net present value of future benefits to be obtained from that resource. Therefore, the valuation coefficient for a long-lived resource may be estimated by determining the current ratios of exchange for identical resources. However, there is empirical evidence that such market data for older style resources is generally unavailable (although it must be stated that further empirical research must be completed before such a conclusion is warranted). The only apparent solution to this problem requires a methodology which would enable the measurer to estimate current replacement cost for an older resource by examination of the current ratios of exchange for new resources which are identical, or at least similar, to the older resources. The energy systems approach appears to offer procedures which would enable a measurer to utilize this type of approach.

It must be stated, however, that the use of current market ratios to obtain indications of the current replacement costs for older, similar resources is not completely free of criticism. First, the newer styles may not be produced by utilization of identical resource inputs and production methods as were used in the production of the older styles. Since what is desired is the most accurate estimate of the reproduction cost of the service capability of the older style using current technology, there must be some way of segregating that portion of the overall difference in price between the two styles which is the result of changes in the productive efficiency for producing the specified productive resource. Second, the currently produced style may not be identical to the older style. That is, technological advancement may result in the newer style being more efficient, in terms of ability to perform the services that such resources are designed to perform, than the older styles. This means the newer style would provide more net services than the older style and this, in turn, would require the net present value of future benefits to be higher for the newer style relative to the older style. Therefore, in order to obtain an "accurate" indication of the replacement cost of the service capability for older styles by examination of current exchange ratios, it is necessary to segregate that portion of the difference in price between the two styles that is due to the difference in input transformation efficiency between the two styles form the overall price change.

Since the general energy system approach uses the current market prices of newer styles in estimating the reproduction cost of older styles, evaluation of the accuracy of the estimates requires examination of the following subhypotheses in giving recognition to the problems described in the preceding paragraph:

1. The energy system's approach provides procedures for identifying the segregating estimates of that portion of a change in the price of a productive resource that is caused by changes in the efficiency of producing the resource.

2. The energy system's approach provides procedures for identifying and segregating estimates of these portions of a change in the price of a long-lived resource which are the result of changes in the input transformation efficiency.

3. There is a reasonable degree of empirical correspondence between an energy system's estimate of the current replacement cost for a long-lived productive resource and the observed ratio of exchange for this same resource in a competitive market transaction.

Segregation of Production Efficiency Changes

In order to evaluate the ability of the energy system's procedures for identifying that portion of a change in the price of a productive resource over time which is due to changes in the productive efficiency for creating that resource, it is necessary to consider the hypothetical examples discussed above when evaluating logical consistency. Consider Example One, Case IV. The data provided may be restated as follows:

	Economic Price Index	Output	Resource Input in BTU's	P_e
1960	100	2000 units	100×10^9	1.00
1965	100	2000 units	80×10^9	1.25
1970	100	2000 units	70×10^9	1.42855

Computation of the exchange ratio per BTU for each year is as follows:

1960: $\$200 \times 10^6 \div 100 \times 10^9$ BTU's =

$.02 per thousand BTU's

1965: $\$200 \times 10^6 \div 80 \times 10^9$ BTU's =
$.025 per thousand BTU's
1970: $\$200 \times 10^6 \div 70 \times 10^9$ BTU's =
$.02857 per thousand BTU's

Here the price paid for the productive resource increased by $.0857 per thousand BTU's or nearly 43 percent during the period 1960-1970. However, restating these ratios of exchange per BTU to reflect the most current productive efficiency shows that the entire 43 percent change in price was due to an improvement in productive efficiency (i.e. the 1970 output required less resource inputs, in terms of energy measuring units, to produce than did the 1960 output) where this improvement was not reflected in the purchase cost of the resource:

$$1960{:}\quad .02 \times \frac{1.00}{1.42855} = \$.02857 \text{ per thousand BTU's}$$

$$1965{:}\quad .025 \times \frac{1.25}{1.42855} = \$.02857 \text{ per thousand BTU's}$$

$$1970{:}\quad .02857 \times \frac{1.42855}{1.42855} = \$.02857 \text{ per thousand BTU's}$$

In other words, the 1970 output was produced using less resource inputs in terms of energy equivalents than the 1960 output, yet the purchase price was not reduced to reflect this resource savings. Furthermore, if the 1960 output had been produced using identical production techniques to those available in 1970, the average price received per BTU would have been equal to that received in 1970, thus indicating no price change. Therefore, an analysis of the hypothetical data indicates that the energy systems approach may indeed enable the measurer to identify and segregate that portion of the price change for a long-lived productive resource which is due to changes in the productive efficiency of making that resource available.

Segregation of Changes in Input Transformation Efficiency

Once again, in order to evaluate whether energy systems procedures allow the measurer to segregate that portion of a change in the price of a productive resource over time which is due to changes in the input transformation efficiency of that resource, it is necessary to consider the hypothetical examples discussed above. Consider Example Two, Case II. The data assumed may be restated as follows:

	Economic Price Index	Output	Resource Input in BTU's	P_e	IT_e
1960	100	2000 units	100×10^9	1.0	.6667
1965	110	2000 units	125×10^9	.8	1.0
1970	120	2000 units	125×10^9	.8	1.0

Computing the exchange ratios per unit of energy for each year is as follows:

1960: $\$200{,}000 \div 100 \times 10^9$ BTU's =
$.02 per thousand BTU's
1965: $\$220{,}000 \div 125 \times 10^9$ BTU's =
$.0176 per thousand BTU's
1970: $\$240{,}000 \div 125 \times 10^9$ BTU's =
$.0192 per thousand BTU's

Restating these ratios of exchange to reflect constant productive efficiency at the 1970 level is as follows:

1960: $.02 per thousand BTU's x $\frac{1.00}{.8}$ =
$.016 per thousand BTU's
1965: $.0176 per thousand BTU's x $\frac{.8}{.8}$ =
$.0176 per thousand BTU's
1970: $.0192 per thousand BTU's x $\frac{.8}{.8}$ =
$.0192 per thousand BTU's

This restated information is communicating the fact that a resource identical to those produced in 1970, in terms of input transformation efficiency, would have sold for $.016 per thousand BTU's if it had been produced in 1960 at 1970 levels of productive efficiency. However, when produced in 1970 it sold for an average of $.0192 per thousand BTU's. Therefore, the average price increased by $.0032 per thousand BTU's or 20 percent between 1960-1970. But an examination of the index of relative input transformation efficiency indicates that the resources produced in 1970 were substantially improved over those produced in 1960. Accordingly, the above estimated ratios of exchange must be restated to reflect the difference in input transformation efficiency as follows:

1960: $.016 per thousand BTU's x $\frac{.6667}{1.0}$ =
$.01067 per thousand BTU's

1965: $.0176 per thousand BTU's x $\frac{1.00}{1.00}$ =
$.0176 per thousand BTU's

1970: $.0192 per thousand BTU's x $\frac{1.00}{1.00}$ =
$.0192 per thousand BTU's

This data may be interpreted as follows. A resource identical, in terms of input transformation efficiency, to one produced in 1970 would have been sold for $.016 per thousand BTU's if it had been produced in 1960 at the 1970 level of productive efficiency. As such, a resource produced in 1960 identical, in terms of input transformation efficiency, to the model actually produced in 1960 would have been sold for $.01067 per thousand BTU's if produced at the 1970 level of productive efficiency (the $.00533 per BTU difference in price reflecting the relative difference in input transformation efficiencies). Accordingly, if the 1970 models produced at the 1970 level of productive efficiency are sold for $.0192 per thousand BTU's in 1970, then it follows that the 1960 models produced at the 1970 level of productive efficiency would sell new for $.0128 per thousand BTU's ($.0192 per thousand BTU's x $\frac{.667}{1.00}$) in 1970. Therefore, the average price in 1970 for a resource identical to the model produced in 1960 is $.0128 per thousand BTU's of energy equivalent input. The relative effects of changes in productive efficiency and input transformation efficiency on prices is summarized as follows:

	Productive Resource	
	1960 Model	1970 Model
Cost in 1960 at 1970 P_e	$.01067 per thousand BTU's	$.016 per thousand BTU's
Cost in 1960 at 1960 P_e	$.0200 per thousand BTU's	$.030 per thousand BTU's
Cost in 1970 at 1970 P_e	$.0128 per thousand BTU's	$.0192 per thousand BTU's
Cost in 1970 at 1960 P_e	$.016 per thousand BTU's	$.0240 per thousand BTU's

This analytical examination of hypothetical examples supports the conclusion that the energy systems approach provides procedures which will enable the measurer to identify and segregate those portions of a given price change resulting from changes in either productive efficiency or input transformation efficiency.

Empirical Correspondence Between Estimated Exchange Ratios and Actual Market Prices Observed in a Competitive Market

Although logical reasoning using hypothetical data, as was shown above, supports the conclusion that the energy systems estimates are accurate, such an assertion requires empirical verification. Empirical verification will take the form of a comparison between energy systems price estimates for a given long-lived resource and the market price which this resource commands in an arms-length transaction. Many market transactions involving older style long-lived productive resources may be observed in the U.S. economy. However, the data limitations discussed above prevent determination of the energy systems generated price estimates. When this data becomes available, it will be possible to empirically verify the accuracy of energy systems price estimates by comparing the estimated ratios of exchange with actual market ratios of exchange observed.

The General Energy Systems Methodology Will Provide Objective Estimates of Current Replacement Cost--An Evaluation

The question being addressed by this portion of the evaluation is whether different groups of C.P.A's would compute substantially identical estimates for a specified resource given the identical factual situation. This is strictly an empirical question which would require an examination of the dispersion of the estimates made by different individual measurers about the average of these estimates in order to reach a warranted conclusion. As the empirical data needed to make the general energy systems method operational is not available at this time, it is not possible to answer this particular question.

CHAPTER VI
SUMMARY AND CONCLUSIONS

In energy systems theory, dollar flows are viewed as information feedback loops which enable consuming units to communicate their economic needs and desires to producing units. These feedback loops function to convey information to producers concerning the type of activity which they should carry on in order to receive the highest reward (in the form of dollars being received for their output). Within a market-oriented economic system, the function of accounting is to collect, process, interpret, summarize, and report the information content of dollar flow feedback loops to those individuals in the social system who influence or make the decisions which direct energy flows toward useful ends. Implicit in the accounting process is the conclusion that the financial statements must aid in the making of correct decisions for resource allocation and utilization.

The purpose of this research effort is to utilize a general energy systems theoretical framework to examine the accounting process with respect to accounting for long-lived productive resources and to suggest some possible modifications which may aid in eliminating the observed weaknesses.

Criticisms of Current Accounting Practice With Respect to Long-Lived Productive Resources

Examination of generally accepted accounting procedures revealed that the use of acquisition exchange ratios as valuation coefficients (for converting heterogeneous quantities of resources into a common, currency-based, measurement base) represented one procedure which could cause improper decisions to be made by users of accounting data. For example, in times of inflation, net income may be inflated and this may result in: (1) income taxes effectively being taxes on capital rather than on income, (2) improper resource allocation, (3) consumer demand for lower prices, (4) demands by labor for higher wages, and (5) demands by stockholders for larger dividends. In other words, decision-makers may be exerting improper control over resource flows via income distribution and other social policy decisions which are based upon the information provided by accountants in financial statements or reports. The decision problems come about because financial information is collected and summarized by accountants applying accounting procedures which make it difficult to generate financial data that is comparable between time periods, industries, and entities. One accounting procedure which is a major cause of this lack of comparability is the use of acquisition exchange ratios as valuation coefficients.

The use of acquisition exchange ratios as valuation coefficients poses two categories of information problems. First, there is the problem of communicating the results of normal operations. As currently computed, the net income figure tends to combine the results of operating activity with the results of resource holding activity. Since different resources are held for different time intervals by different firms, evaluation of a single income figure sheds little light on the operating results of a given firm for a given time interval relative to either the operating results of other firms for an identical time interval or its operating results for prior time intervals. Second, there is the problem of communicating information concerning current financial condition. The summation of currency measurement aggregates derived by using acquisition ratios of exchange from many different prior time intervals as valuation coefficients is virtually meaningless as an indication of the quantity of resources currently available to management.

The debate among accountants concerning the use of historical acquisition exchange ratios versus the use of current exchange ratios (such as reproduction cost, replacement cost, market values, and so on) as valuation coefficients can be analyzed in terms of two basic questions: (1) Should gains and losses resulting from resource holding activity be recognized and reported? and (2) How should such holding gains and losses be measured?

Detailed examination of previously completed research showed that resolution of the first question requires a determination as to whether the use of current exchange ratios as valuation coefficients (i.e. the recognition and reporting of holding gains and losses) would provide more useful financial data for decision-making purposes than the use of acquisition exchange ratios. Furthermore, it was concluded that alternative accounting procedures, such as historical cost versus current cost as valuation coefficients, must be evaluated by comparing the actual motivational responses of decision-makers to accounting information (calculated using each alternative procedure) with some "ideal" response which is considered desirable for the system as a whole. The accounting procedure which results in the "best" response is the one to be used. However, such an investigation was considered beyond the scope of this particular inquiry.* Therefore, this research activity was constrained to consideration of measurement questions.

A Description of the Problematic Situation

The defined problematic situation is to develop and evaluate the general energy systems approach as an effective methodology to be used in generating statistical estimates of reproduction cost and replacement cost. The ends-in-view necessary in evaluation of a general energy systems price model were tentatively established as follows:

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*See Chapter I--Assumptions

1. The statistical estimates must be objective. That is, the methodology for generating the numbers must be logically consistent and there must be a reasonable degree of empirical correspondence among a given group of observers or estimates.

2. The methodology must provide reasonably accurate estimates. A common criticism of nearly all proposed methods of estimating current cost by reference to current market transactions for new similar resources is that there is not an objective method of segregating a given price change into the following components:

    a. That portion of the change due to supply-demand conditions.

    b. That portion due to change in the productive efficiency of combining the inputs necessary to produce the resource.

    c. That portion due to the fact that technological advancement has enabled the current "equivalent" resource to be superior in some way relative to the prior resource.

The preliminary working hypotheses for evaluating the proposed measuring system, formulated in light of the stated ends-in-view, may be restated as follows:

1. The conceptual framework of the general energy systems approach is logically consistent.

2. The general emergy systems approach provides reasonably accurate estimates of the current reproduction (or replacement) cost of a specified long-lived productive resource.

3. The energy systems approach for estimating current replacement or reproduction cost can be made operational such that there is reasonable statistical correlation between the estimates provided even when different groups of observers apply the measurement procedures in generating estimates.

Description of the Energy Systems Approach

The examination of the energy systems approach begins with an identification of energy. Basically, work was found to be a rather abstract term which implies a force acting upon an object which either changes the spatial position of the object or serves to change the object's shape or form. Power, then, was defined as work per unit of time (or the rate at which useful work is done). Energy is a term with a double meaning: it can refer to the ability to do work or it can imply the actual accomplishment of work. However, it was stated that Newtonian physics holds that the quantity of energy in the universe is constant; thus, energy is never lost or gained. Therefore, man neither creates energy nor destroys it. When it is said that energy is "created," what is meant is that man has increased its supply at the time and place and in the form that he needs it. This is the First Law of Thermodynamics and, as seen from the above comments, it requires that energy be conserved. The Second Law of Thermodynamics requires that some of the available energy be used up in any process involving work, leaving less available energy in the resulting product. Therefore, man consumes or degrades energy when he performs the tasks necessary to make energy available to serve his purposes.

Energy and Man

Next the historic conversion of energy and matter by man into the form (or time or place) for it to be useful to him was analyzed, with particular reference to the evolution of the impact of energy on man's social system. This historical examination led to the conclusion that energy is very important to man given his particular cultural and regional setting. As heat, energy enables man to inhabit regions otherwise too cold for human occupancy; it enables man to separate metals from ores, to cast and otherwise reshape metals and other materials, to render foods edible and palatable, and to protect himself from disease by sterilization of water, food, and contaminated objects.

As light, energy lengthens the day, stretching the time available for work and recreation into periods of natural darkness. Also, it extends man's vision into the subterranean world from which come the earth's coal, metals, and other minerals.

As motion, energy changes the location, size, or shape of material by pushing, pulling, lifting, rotating, twisting, cutting, stretching, or compressing. It enables man to transport materials from where they are found to where they can be processed and then to where the processed products are needed. It enables man to move from where they are to where they would like to be. Other changes are brought about by electrolysis (such as the refining of metals and the separation of elements); by electromagnetic waves (such as the transmission of light and sound between broadcasting stations and radio or television sets); and by sound itself.

In general, it may be stated that very few of the economic goods used by man are found in their raw state in nature. Rather, they are the result of the transformation of some raw materials which are available in their unprocessed state from nature. As stated above, conversion of naturally occurring raw materials into economic goods of the type desired by man requires performance of work which, in turn, requires degradation of energy (the second law of thermodynamics). Therefore, in energy systems terminology, economic goods are described as high probability natural resources which have been processed, by degrading low entropy potential energy in the performance of work, into low probability, highly organized forms of the type desired by man. Thus, all economic goods appear to be outputs of energy conversion processes. This leads to the conclusion that the energy equivalent of the work needed to produce a particular output can be stated; and as such, energy equivalents can be used to measure each of the heterogeneous outputs (goods and services) of the economic system in terms of a common measuring unit. Furthermore, it may be concluded that energy, in the form of goods and services, flows in the opposite direction to money, which serves both as the exchange payment mechanism for goods and services and also as the principal common denominator for expressing all output in terms of a single measurement unit.

Energy and Economics

Integrating energy systems concepts with currently accepted economic price theory and macro-economic theory shows that economics appears to be fundamentally concerned with studying, interpreting, and predicting the motivational-behavioral response patterns of both producer units and consumer units to the information being communicated via the currency-based feedback, reward loops, which flow in the opposite direction to energy flows (the energy flows taking the form of goods and services). This conclusion could be logically supported by developing energy models of man's economic activities and then comparing these models with the energy models developed for natural systems where no feedback loops of man's currency exist. The explanations and illustrations of this phase of analysis imply that all systems have an information-communication component in the form of feedback reward loops. These feedback loops convey information to each component within a system as to how well that component's output is being received by the consumer components within the system. The study of economics shows that in man's social system, the feedback information loops are the currency flows between entities. The economic fact is that entities, or system components, which do not provide output useful (where "useful" means that demand is either greater than, or in equilibrium with, supply) to other components may not receive as much for their output as must be paid for the inputs needed to produce that output. These components can either continue to operate at a loss until they utilize all the resources available to them, at which time their output flow ceases and the firm terminates, or they can adapt to the system and reallocate their resources to produce "useful" output. In either case, analysis of the currency loops, in accordance with economic price theory, provides indications of a given component's relative importance to the other components within the social system.

Accounting--An Information Subsystem

Accounting functions as the information provider to various entities operating within the social system. In other words, the accounting component of the information-communication system exists in order to make available to decision-makers the economic information communicated by way of currency feedback loops. Accounting performs this function at the level of a single accounting entity by analyzing each entity's specific feedback loops in order to interpret, collect, process, summarize, and report the relevant data concerning both the results of economic activity for a given time interval and the economic status of specific entities at a given instant of time. Thus, the accounting component of man's social system enables the individuals who operate the energy control levels to continually monitor the currency flow feedback loops. By proper use of the accounting information, decision-makers can control the behavior patterns of the system components, which they have the power to influence, in response to the needs of other components of the system, where these needs are communicated via the currency flows. In other words, within the limits of particular system components (for example, financial or technological limits), energy flows may be reallocated in order to produce the goods and services in great demand rather than those in oversupply. Thus, a particular producer unit is not necessarily condemned to eventual destruction if its reward loop from consumers is either broken or inadequate relative to its needs, because it may be able to reallocate its remaining stored resources and produce an output which will again establish the necessary reward loop from other components (i.e. that which is demanded by the other components) of the system. Moreover, accounting information is not only communicated to the individuals who operate the control levers for directing energy flows, but also to other individuals who are interested in, or who may exert control over, the control operator's responses to the changing money flow data (such as stockholders, in the case of a corporation).

This state of affairs is contrasted to that observed in natural systems, where a system component supplies its outputs to consumer components and is rewarded by receiving the recycled inputs needed in order to exist and produce more output. If the reward feedback loop of inputs is cut off for some reason, the producing component continues to provide its output until all its stored input resources are exhausted, then it drops out of the overall system through death. This evolutionary process is referred to as the natural selector and it operates to insure that all components of a system operate in a manner such as to guarantee the survival of the overall system.

Energetics in Economic Analysis

The purpose of Chapter III of this inquiry was to describe energy systems theory and draw conclusions with respect to the validity of the energy systems approach in terms of economic theory. Basically, it was concluded that the energy systems approach in no way conflicts with economic value theory. Rather, the energy systems approach complements economic theory as it adds a new measuring dimension for economic analysis in terms of the overall social system. Once it is established that energy flows are related to dollar flows and that all economic goods can be measured in terms of the energy equivalents used in making them available, there are two common denominators available for expressing heterogenerous outputs in terms of a common measuring unit. Furthermore, an average price per unit of energy can be determined by dividing the dollars received for any output of an economic input-output node by the energy equivalents for the input resources utilized in making the output available. This relationship makes it possible to compare energy values (i.e. energy equivalents) with money prices. Thus, energy equivalents may be used to measure quantities and dollar flows to measure value (or the subjective utility to be gained by owning a specified output as given the supply-demand conditions at a given instant in time). This relationship provides the basic framework for an energy system's ratio of exchange measurement model.

The Energy System's Ratio of Exchange Measurement Model

Analysis of the general energy systems approach in terms of economic theory provided insight into the behavior of the average price of energy. It became clear that the average price for energy changes if either the money flow or the energy flow changes. Money flow may change because of a number of things:

1. Changes in the demand or supply for resource inputs necessary to the production of the particular good in question (this will change the production cost for the good which must eventually be reflected in the price of the good given a properly functioning market economy);
2. Changes in the supply of the particular good itself; and
3. Changes in the demand for the particular good in question.

In addition to changes in consumer utility functions over time, changes in demand may occur because of changes in output quality (i.e. changes in the ability of a given output good to perform the functions it was created to perform). Since a basic expected use of the energy systems ratio of exchange model is to enable accountants to use current market prices for new productive resources as an indicator of current values for older styles of similar productive resources and since the older styles may not be as efficient as the newer styles, some method of segregating that portion of the price of the newer styles which is due to the change in quality must be devised in order to be able to determine accurate estimates of the current price for the older styles by way of examination of market prices for the newer style. The energy systems model uses an input transformation efficiency index (IT_e) to adjust currently observed market prices for the new styles. Such adjusted prices should equal the current market price for a newly constructed resource identical in style to the older one (this index is described in Chapter IV and its implementation illustrated in Chapter V of this inquiry).

An energy flow varies because of changes in the social system's efficiency in transforming resource inputs into final goods and services. Because the problem being considered by this inquiry is to estimate current reproduction cost, a method must be developed to enable measurers to determine the most recent year's productive efficiency relative to the productive efficiency of prior years. Then all energy flows are restated in terms of the most recent year's productive efficiency. The index of productive efficiency (P_e) was designed to accomplish this objective. It is also described in Chapter IV of this inquiry and its implementation illustrated in Chapter V.

Based upon these concepts, the energy system's economic price model for estimating replacement (or reproduction) ratios of exchange was formulated. The model may be expressed in the following form:

$$P_{est} = \frac{P_i q_i}{E_i}$$

The procedures for implementing this model are illustrated in Chapter IV and the modifications by way of both P_e and IT_e are described and illustrated in Chapter V of this inquiry.

Evaluation of the General Energy Systems Ratio of Exchange Model

The general energy systems price model was evaluated in Chapter V in terms of the three preliminary working hypotheses presented and developed in Chapter I. The basic conclusions of this evaluation may be stated as follows:

1. The general energy systems model is internally consistent. That is, application procedures may be devised which enable the measurer to operate in all economic environments without any logically conflicting results. For instance, the energy systems approach is applicable to situations where prices change because of either changes in productive efficiency or input transformation efficiency as well as to situations where price changes are due to

all other supply-demand interactions which tend to influence prices. In addition, the estimates which are obtained by applying the energy systems approach are logically consistent with economic price theory. That is, productive resources identical in all respects are assigned identical currency values which is what an economic investigator would expect. Furthermore, productive resources identical in all respects, except that one is more efficient than the other, would be assigned currency values which would vary in proportion to their differences in efficiency. This is also what would be expected in terms of economic price theory provided that market prices reflect the net present value of future benefits. It should be noted, however, that future empirical investigation is needed to confirm the economic assertion that the difference in price between two resources identical in all respects, except that one is more efficient in transforming input into output than the other, will reflect only the difference in efficiency.

2. The energy systems approach does provide procedures for identifying and segregating that portion of a price change for a specified long-lived productive resource over time which is caused by either changes in productive efficiency or changes in input transformation efficiency. However, this does not guarantee the "accuracy" of the estimate for the current reproduction cost of the resource. Accuracy is a term which refers to a reasonable degree of

empirical correspondence between a measure of an object and the ideal measure of that object. The most frequently stated "ideal measure" for a long-lived resource is the net present value of its future benefits. Generally, these "net benefits" are very difficult to measure precisely. However, in a perfectly competitive market the discounted present value of future benefits is believed to be equal to the current market price (i.e. the market price represents the collective judgments of all purchasers of a particular resource concerning the present currency worth of the future services). Therefore, a conclusion that the energy systems approach provides accurate estimates of the currency value of long-lived resources is warranted only if the estimated ratio of exchange closely approximates the actual market ratio of exchange in an arms-length transaction. This empirical question cannot be resolved at this time because of lack of data.

3. Objective in this inquiry refers to a reasonable degree of empirical correspondence between the estimates provided by different measurers. Accordingly, whether the energy systems approach will provide objective estimates of current replacement cost is an empirical question which cannot be resolved at this time due to the data limitations.

The Duties of the AICPA

It must be noted that the operation of the general energy systems measurement model is strongly dependent upon the cooperation of the American Institute of Certified Public Accountants. Because of the nature of the input data necessary to the operation of this model, it is felt that data collection and summarization must be accomplished at the professional level. Accordingly, it is necessary to have a continuing AICPA Committee whose sole function is to analyze U.S. economic and energy data in order to generate the appropriate average ratios of exchange per thousand BTU's of energy equivalents as well as the indexes of productive efficiency and relative input transformation efficiency.

Final Comments

Although it may appear that the data required to implement the energy systems measurement procedures is virtually impossible to obtain, it may be stated that initial investigation has shown that all the necessary data is available. It merely must be restated in the proper form for the general energy model. Once the initial collection phase is complete it will be a relatively easy and inexpensive process to obtain the statistical input data from national statistics currently published annually.

APPENDIX

This appendix is included in order to describe the basic concepts of this paper in terms of energy flow diagrams. Figure 3 represents an energy flow diagram of a hypothetical company, XYZ, for the year 1970. During 1970, company XYZ purchased some capital structure (assume the cost was $250,000 for a new manufacturing facility) and utilized it with other purchased inputs (8) to produce output, some of which was sold (3). The money flows (4, 5, and 6) represent economic feedback loops which serve to direct energy (i.e. the inputs represented by 7 and 8) to its most "useful" ends. This process is made operational in a market economy because firms direct energy use to that use that produces the greatest excess of money inflow over money outflow (i.e. the goods in shortest supply relative to demand will be produced). Accounting is that subsystem of the social system, responsible for communicating the information content of money flow loops to the decision-makers who direct energy use. Accountants report the results obtained by matching the dollar outflows (4 and 6) against the dollar inflows (5) as part of this communication process. However, in the case of the capital structure

FIGURE 3 - LEGEND

1. The capital structure owned and utilized by a producer unit.

2. The inventory of output for a given producer unit. In the case of XYZ this would represent a storage of fabricated metal products.

3. The outflow of fabricated metal products as they are sold to cutomers.

4. The dollar payments by XYZ company necessary to purchase capital structure.

5. The dollar inflow resulting from the sale of fabricated metal products.

6. The dollars paid by XYZ in order to obtain the inputs, other than capital structure, necessary to the production of its output.

7. An inflow representing the acquisition of capital structure.

8. Inputs of fossil fuel, labor and services, raw materials, and manufactured supplies from other companies.

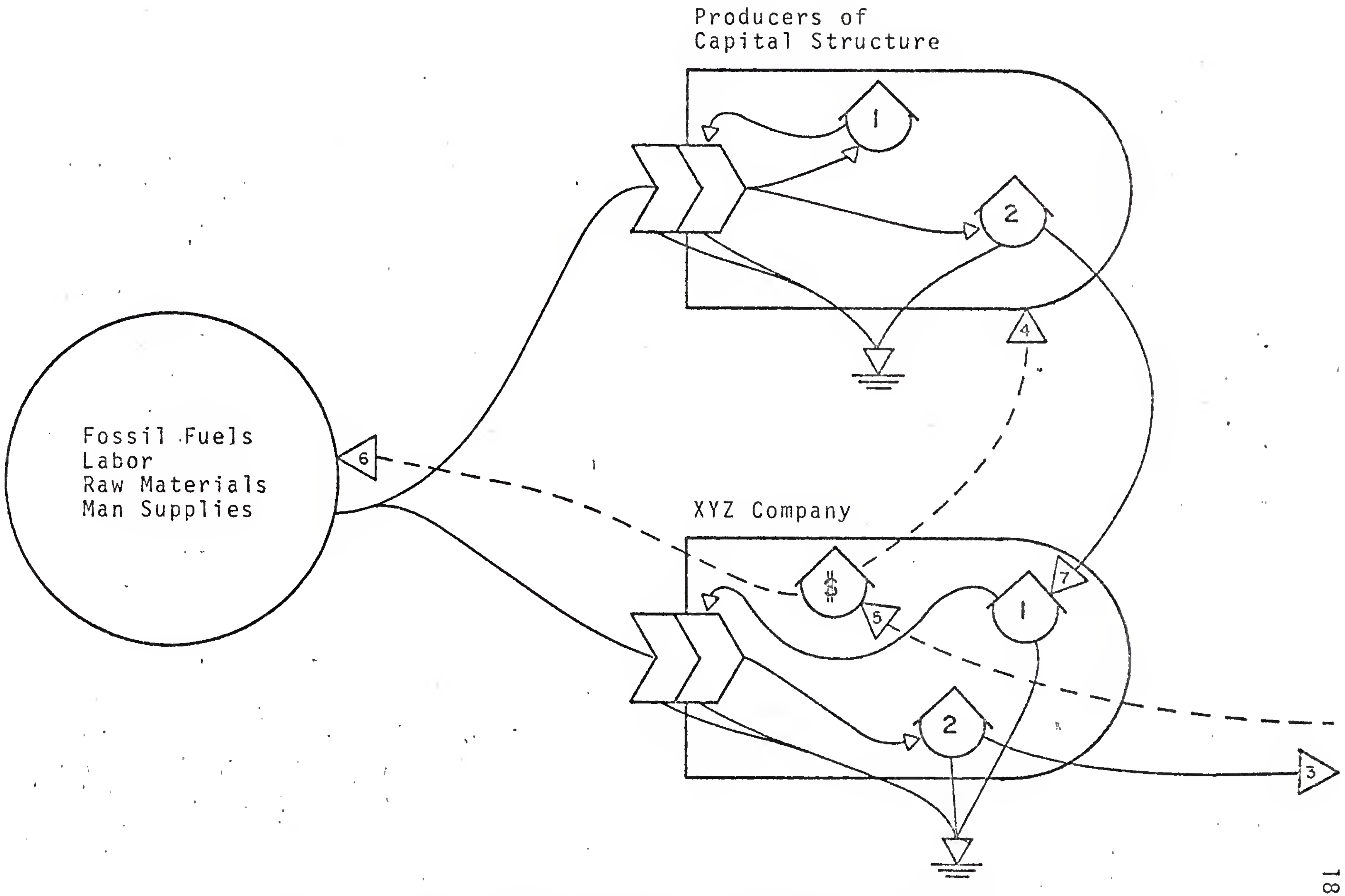

FIGURE 3. XYZ COMPANY: ENERGY DIAGRAM OF A PRODUCER OF FABRICATED METAL PRODUCTS (1970)

input (i.e. long-lived productive resources) a problem arises.

The Accounting Problem

In our example, XYZ company acquires capital structure for $250,000 in 1970. But this long-lived input is used for producing output for many future periods. Therefore, it would not be appropriate to match the $250,000 outflow necessary to purchase the capital structure against the inflow observed during 1970. Instead, the $250,000 outflow represents a cost which must be held in suspense and allocated to future accounting periods, during which time the capital structure is used for producing output. One obvious accounting problem is how to make this cost allocation over the capital structure's useful life. This problem is not considered in this inquiry; therefore, assume the useful life is ten years and the resource is degraded at a constant rate over that period. This means $25,000 of the $250,000 outflow will be assumed to flow out each year.

A second problem, which is the primary topic of interest here, occurs because prices change over time. Consider Figure 4, which is identical to Figure 3 except that it depicts ABC company in 1971. Assume the manufacturing facility purchased by ABC company is identical in all respects to that purchased by XYZ in 1970, except that

FIGURE 4 - LEGEND

1. The capital structure owned and utilized by a producer unit.
2. The inventory of output for a given producer unit. In the case of ABC this would represent a storage of fabricated metal products.
3. The outflow of fabricated metal products as they are sold to customers.
4. The dollar payments by ABC company necessary to purchase capital structure.
5. The dollar inflow resulting from the sale of fabricated metal products.
6. The dollars paid by ABC in order to obtain the inputs, other than capital structure to the production of its output.
7. An inflow representing the acquisition of capital structure.
8. Inputs of fossil fuel, labor and services, raw materials, and manufactured supplies from other companies.

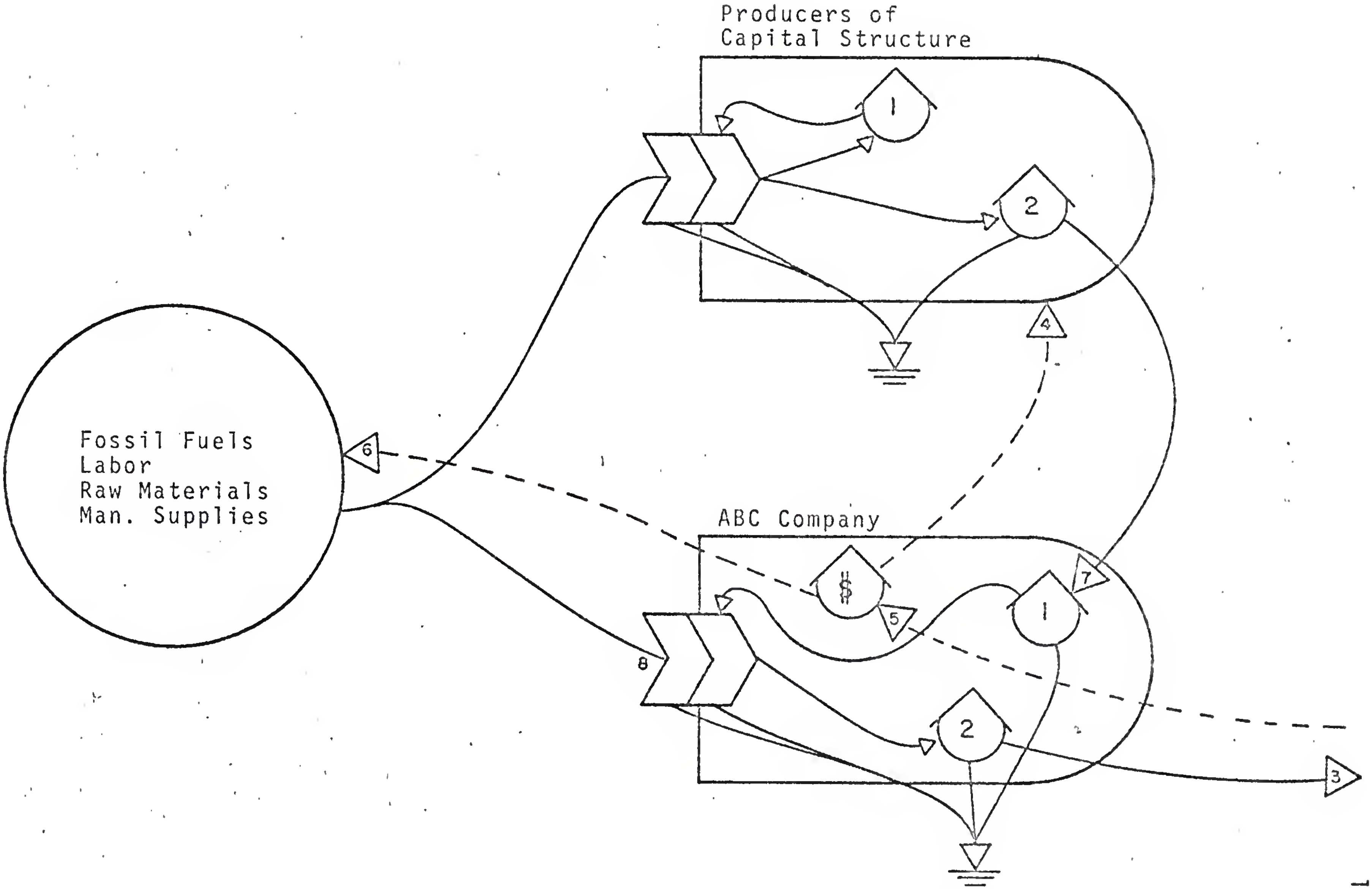

FIGURE 4. ABC COMPANY: ENERGY DIAGRAM OF A PRODUCER OF FABRICATED METAL PRODUCTS (1971).

it costs $300,000 due to inflation. This means during any future year, such as 1972, ABC company will match $30,000 against revenue representing the cost of services purchased in the form of capital structure, but these services are identical to those purchased by XYZ company for $25,000. When this situation is multiplied thousands of times and involves a decade or more of acquisitions, a serious question is raised concerning the effectiveness of accountants in communicating the information content of money flow feedback loops. This is particularly disturbing when it is realized that erroneous allocation of resources may result from an improper interpretation of financial statements.

The Energetic Solution

The only apparent solution to this problem is to adjust the dollar cost associated with capital structure acquired during previous accounting periods so that the associated money flow in any future period reflects the most current cost of acquiring services identical to those being consumed as the capital structure is utilized. In other words, the money flow must be adjusted so as to accurately represent the current price of the energetic contribution of each firm's capital structure to its operations. Only if this is done will accountants be reporting information in such a manner that firms, even within the same industry, can be compared.

FIGURE 5 - LEGEND

1. The capital structure owned and utilized by the producers of metal working machinery.
2. The inventory of completed metal working machinery which is the output of the sector.
3. The dollar storage for the illustrated sector. It represents the currency equivalents of all the assets owned.
4. The flow of metal working machinery as it is sold to the costomers such as XYZ and ABC.
5. The inflow of dollars earned by selling metal working machinery.
6. The inflow of capital structure purchased by this sector.
7. The outflow of dollars to purchase the capital structure.
8. The inflow of necessary labor and services.
9. The inflow of necessary raw materials.
10. The inflow of necessary manufactured supplies from the other firms.
11. The inflow of necessary fossil fuel.
12. The outflow of dollars to pay for labor and services, raw materials, manufactured supplies, and fossil fuel.

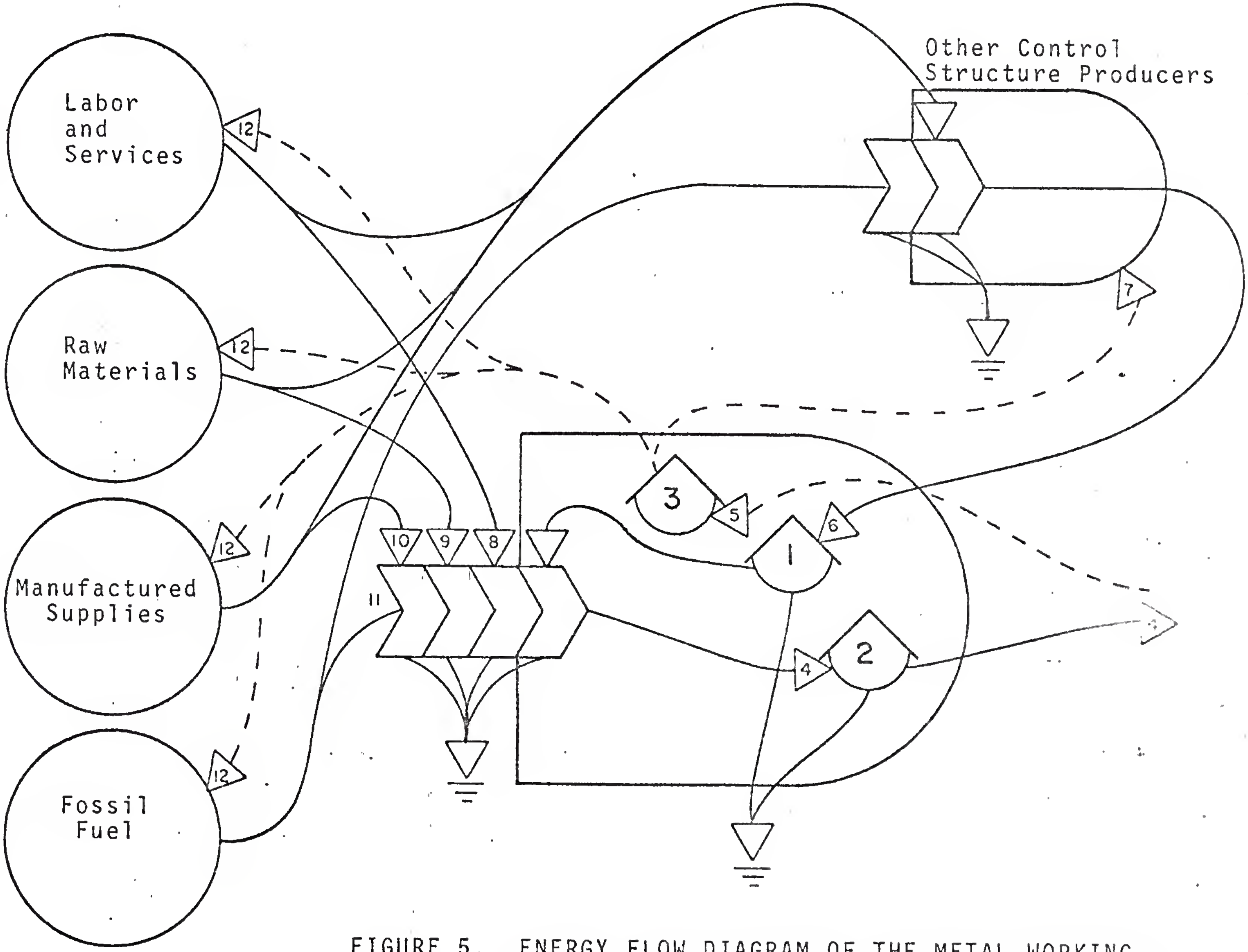

FIGURE 5. ENERGY FLOW DIAGRAM OF THE METAL WORKING MACHINERY SUBSYSTEM OF THE CAPITAL STRUCTURE PRODUCER'S SYSTEM

This paper purposes an energy systems approach for making this money flow adjustment. It is believed that the energy systems methodology will overcome some of the more important conceptual objections to the various economic adjustment methods previously proposed. Figure 5 illustrates the proposed energy systems methodology. In this hypothetical only one capital structure sector is considered--the producers of metal working machinery sector. Obviously, the entire capital structure producer sector should be considered in measuring any complete manufacturing facility but one is sufficient to illustrate the energetic concepts involved. Inflows 6,8,9,10 and 11 represent the resource inputs necessary to produce metal working machinery. Accordingly, each input has its energetic contribution. However, for reasons to be explained in the discussion concerning Figure 6, the energy equivalent of each metal working machine will be the sum of heat equivalent of the fossil fuel used plus the fossil fuel heat equivalent of the labor and services used in producing that machine. The energetic contribution of the raw materials, the purchased manufactured supplies, and the capital structure will be assumed to flow out the heat sinks. The measured energy equivalent for each machine can be related to its sales price and the average value per unit of energy degraded in producing a metal working machine can be computed. This "price" per unit of energy can be used to adjust the undepreciated energy equivalents of metal working machinery acquired in earlier time periods to more clearly reflect the current dollar cost.

An Illustration

In order to illustrate the application of this method assume \$150,000 of XYZ's \$250,000 capital expenditures in 1970 was for metal working machinery. Furthermore, assume producers of metal working machinery had total sales of \$800 million in 1970 and that the output sold required 53.34×10^{12} BTU's of energy to produce (i.e. the sum of the direct fossil fuel degraded plus the labor and services fossil fuel equivalent). This means the dollar to energy ratio is \$.015 per thousand BTU's. \$150,000 ÷ \$.015 per thousand BTU's means XYZ purchased the equivalent of 10×10^9 BTU's of energy. This means each year's depreciation is 1.0×10^9 BTU's in energy equivalents and multiplying by the current year's dollar to energy ratio for the producer's of metal working machinery will give the appropriate money flow.

Assume \$180,000 of ABC's \$300,000 of capital expenditures in 1971 was for metal working machinery. Assume total sales of metal working machinery equalled \$960 million in 1971 and that quantity of output also required 53.34×10^{12} BTU's of inputs to produce. The average value per unit of energy degraded in producing metal working machinery is \$.018 per thousand BTU's. Therefore, ABC company also purchased 10 x 10^9 BTU's in the form of metal working machinery. ABC's annual depreciation will also be 1.0 x 10^9 BTU's; thus, the money flow will be equal to XYZ's money flow which is proper as each is consuming identical services at an identical rate. Modifications of these procedures are illustrated in Chapter V to handle varying input transformation efficiency as well as varying productive efficiency.

The Computation of Energy Equivalents

In order to understand the proposed methodology for measuring the energy equivalents of an economic good it is necessary to consider the U.S. economy as a system. Figure 6 illustrates a simplified energy flow diagram of the U.S. economy. In computing an energy equivalent measure for an economic good, it is necessary to distinguish goods which are to be used as fuels from goods which are not. For instance, the output from the fossil fuel sector consists of fuels whereas the outputs of the manufacturing sector are not. In general, this writer feels the energy equivalent of a fuel should be equal to the heat equivalent of that fuel. On the other hand, the energy equivalent of a nonfuel good should be the sum of the heat equivalents of the fuels consumed in producing that good plus the heat equivalent of the labor services utilized.

FIGURE 6 - LEGEND

1. The stock of capital structure owned and utilized by a specified sector.
2. The stock of finished output from a sector.
3. The flow of capital structure into a sector.
4. The annual flow of fossil fuel products.
5. The annual flow of food products.
6. The population of the United States.
7. The annual flow representing consumer durables purchased by the population.
8. The annual flow of consumer nondurables, other than food, purchased by the population.
9. The annual flow of labor and services. Measured in energy terms by the heat equivalent of the food plus the fossil fuel consumed directly by the labor force.
10. The annual flow of goods other than consumer goods, fuels, and capital structure.

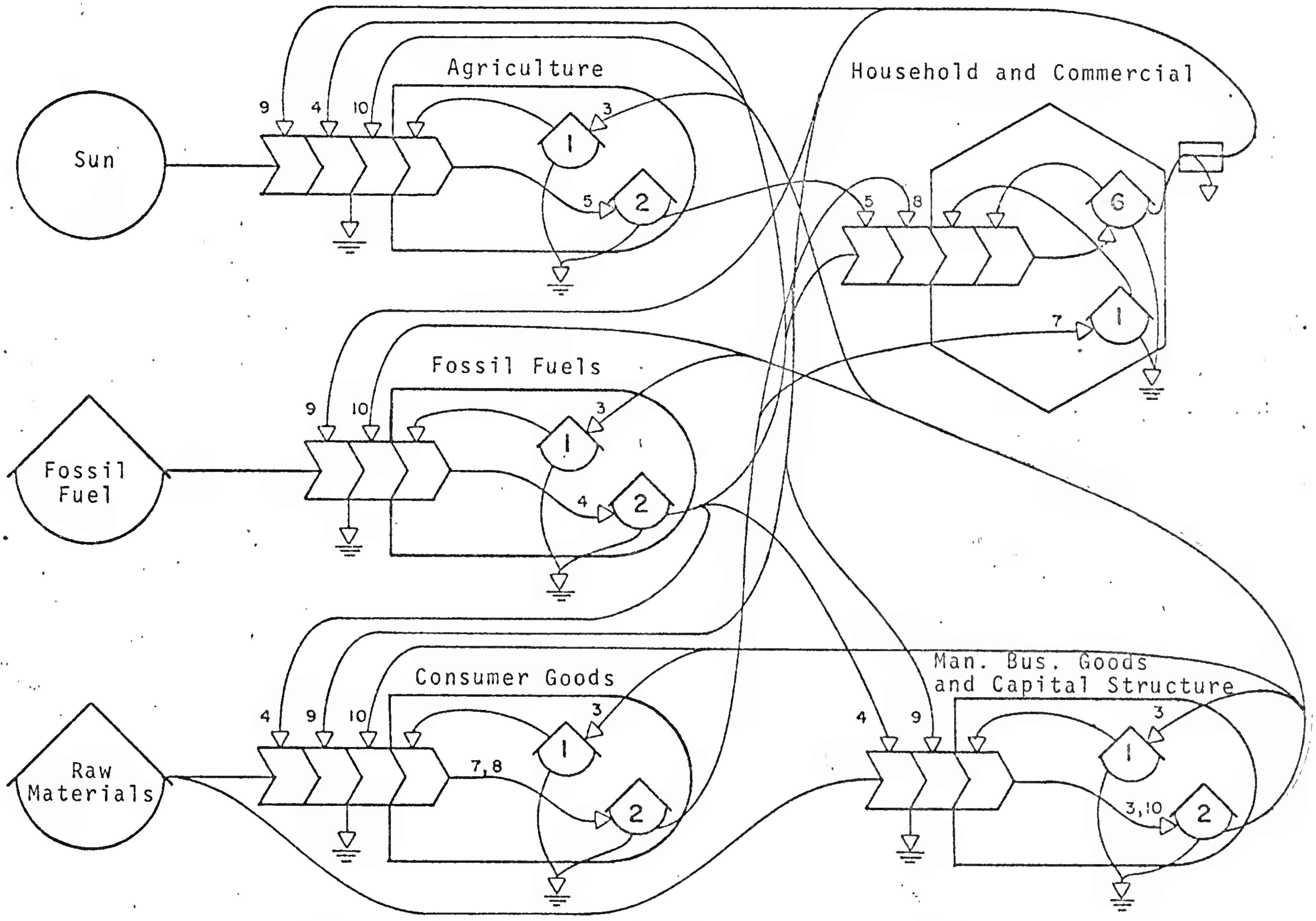

FIGURE 6. ENERGY FLOW DIAGRAM OF THE U.S. ECONOMY

The heat equivalent of the labor services is the sum of the heat equivalent for the direct fossil fuel consumption in the household and commercial sector plus the heat equivalent of the food consumed in that same sector. In reality, food is a fuel and should be measured by the fossil fuel equivalent of its caloric value. However, this amount is insignificant relative to the fossil fuel energy consumed by the agricultural sector. Therefore, it is felt a more accurate energy equivalent is obtained by computing the energy equivalent of food as being equal to the sum of the heat equivalent of the fossil fuel used in the agricultural sector plus the heat equivalent of the solar energy input (stated in a constant fossil fuel quality).

It is well noted that this method of computation does not sum up all the energy degraded in the production of any given economic good. As shown in Figure 6 there are inputs other than labor and fossil fuel and each has its own energetic contribution. However, as also shown in Figure 6 each sector loops back to another. Therefore, including all energetic contributions leads to an energy model in which feedback energy is counted twice, once as a primary input and once as a feedback. Thus, the model tends to be unstable. It is felt that the proposed measurement method adequately depicts the energetic contribution of direct fuel use to the production of any economic good (including the direct fuels needed to sustain the labor system).

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BIOGRAPHICAL SKETCH

Jesse Varnel Boyles III was born August 21, 1946, in Lakeland, Florida. He was educated in the Polk County, Florida public school system graduating from Summerlin Institute at Bartow in 1964. Mr. Boyles received a Bachelor of Business Administration degree with a major in finance from the University of Florida in 1968. After receiving an honorable discharge from the U.S. Army, Mr. Boyles returned to the University of Florida and received a Master of Business Administration Degree in Accounting in 1971. Late in 1971, Mr. Boyles qualified as a Certified Public Accountant in Florida and entered the University of Florida to begin work on his doctorate. Since 1971 he has been employed either as a part-time or a full-time instructor at the University of Florida as well as a practicing tax consultant.

Mr. Boyles married the former Mariana Kathleen Brown of the Panama Canal Zone. He is a member of Beta Alpha Psi, national honorary accounting fraternity, Beta Gamma Sigma, national honorary business fraternity, and both Florida Blue Key and Omicron Delta Kappa, leadership honorary fraternities. Also, he is a member of the American Institute of Certified

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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Professor of Accounting

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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